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41 pro tips and tricks to turn your system into a dream PC

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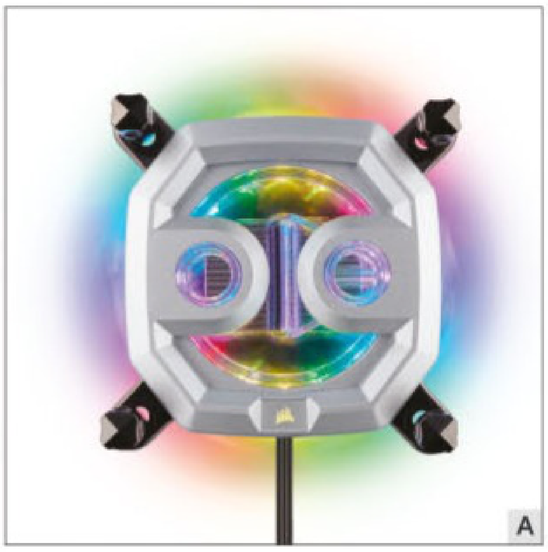

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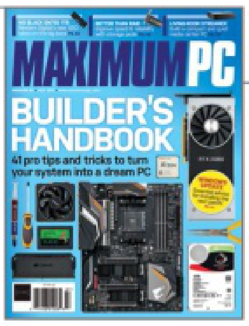

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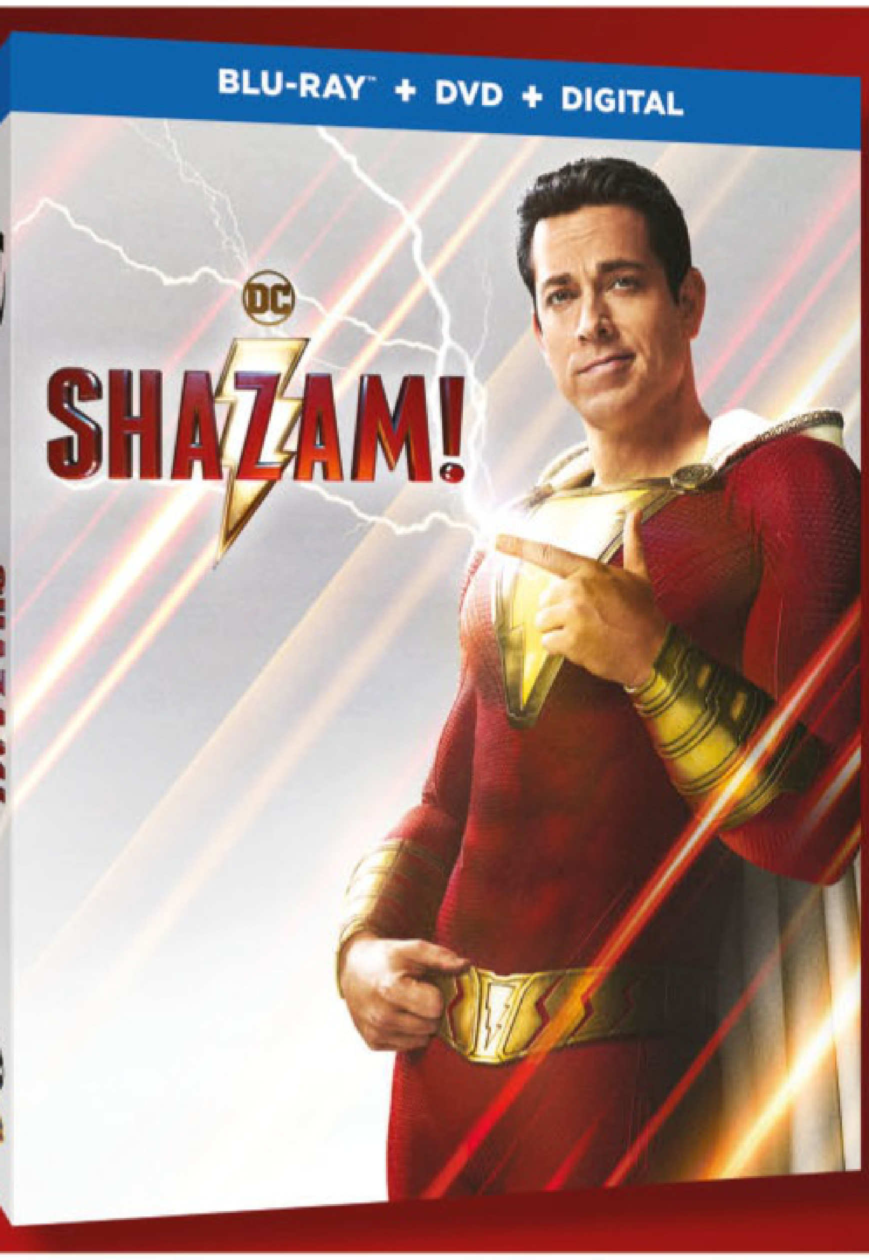
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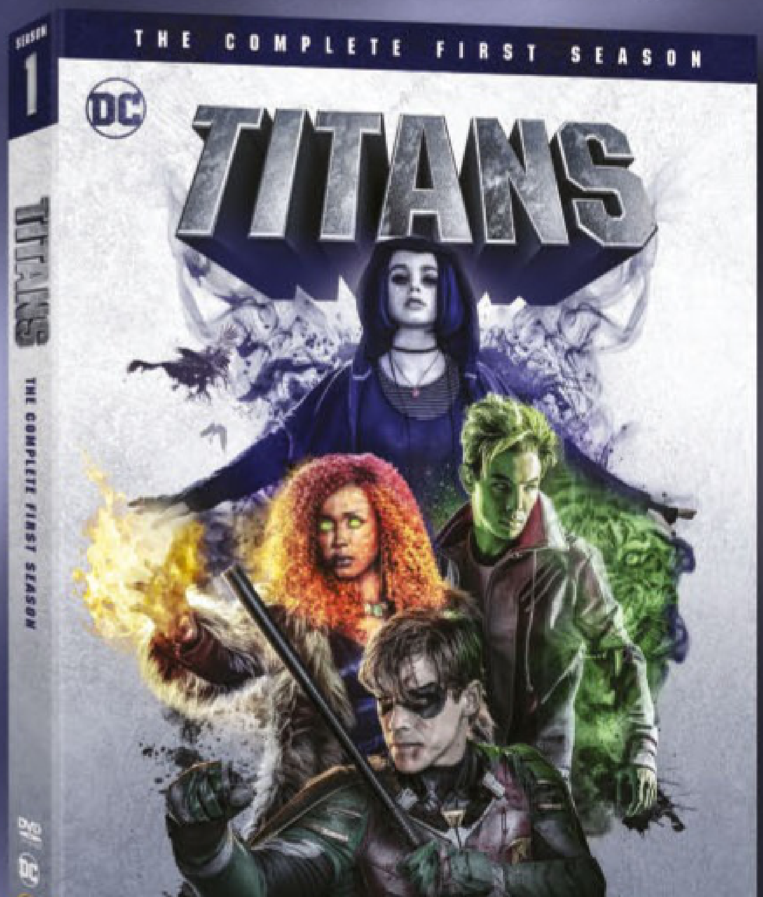
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Contributing Writers: Jonni Bidwell, Alan Bradley, Alex Campbell, Alex Cox, Nate Drake, Ian Evenden, Anthony Howes, John Knight, Jeremy Laird, Chris Lloyd, Les Pounder, Zak Storey, Mark Wyciślik-Wilson
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ART
Art Editor: Fraser McDermott
Photography: Neil Godwin, Olly Curtis, Phil Barker
Cover photo credits: Future PLC

BUSINESS
US Marketing & Strategic Partnerships: Stacy Gaines, stacy.gaines@futurenet.com
US Chief Revenue Officer: Luke Edson, luke.edson@futurenet.com
East Coast Account Director: Brandie Rushing, brandie.rushing@futurenet.com
East Coast Account Director: Michael Plump, michael.plump@futurenet.com
East Coast Account Director: Victoria Sanders, victoria.sanders@futurenet.com
East Coast Account Director: Melissa Planty, melissa.planty@futurenet.com
East Coast Account Director: Elizabeth Fleischman, elizabeth.fleischman@futurenet.com
West Coast Account Director: Austin Park, austin.park@futurenet.com
West Coast Account Director: Jack McAuliffe, jack.mcauliffe@futurenet.com
Director, Client Services: Tracy Lam, tracy.lam@futurenet.com

PRODUCTION
Head of Production: Mark Constance
Production Manager: Vivienne Calvert
Project Manager: Clare Scott
Production Assistant: Emily Wood

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Alan
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BUILD YOUR PC AS IF IT'LL BE ON SHOW—IT'S WORTH THE EFFORT

WE'RE USED TO BUILDING PCs here at *Maximum PC*. It's what we do. We often take it for granted. In our defense, we piece together at least one machine every month, and sometimes there can be a couple of other rigs needed as well, which means that over a year, we can easily hit 20 builds. And as with anything you do a lot, there are numerous techniques, corrections, and nuanced changes that we instinctively do without really thinking about them.

This issue, we attempt to distill this knowledge down on to the page, so you can benefit from our years of experience, hopefully ensuring that your next build is as smooth as possible, and potentially turning a perfectly capable, if unexciting, system into something you're truly proud of. Our "Builder's Handbook" starts on page 26, and it's absolutely the sort of article that's worth keeping until the next time you ease a motherboard into a case.

It's also the sort of feature that's worth having with you if you like the look of the media center we build on page 70. This is the kind of system that will look good under your TV, thanks largely to the Fractal Design Node 202 chassis we've used. Cases can be important when it comes to stamping your own sense of style on a system, but when you're looking at a media center build, fitting in with your existing furniture is essential (as is keeping fan noise levels down to an absolute minimum—which is one of the reasons why we didn't slide a discrete graphics card into the build, even though there is room for it).

We also look at what's lined up for the next big Windows update. Microsoft is doing a good job of introducing useful new features with these updates, and while they haven't always gone smoothly, there's a clear move with this patch to improve the whole update process. There are a few subtle quality-of-life changes that are worth reading up on as well, so turn to page 24 to find out what Microsoft's latest has in store.

We have two other big features this issue: The first looks at taking control of your own smart home with open-source software (page 36), while those interested in running your own NAS should turn to page 48 to discover the joys of storage spaces. This system for handling drives is included in Windows, but it's limited by default. There is a way to unlock more advanced setups though, which is where our feature comes in. Once configured, it's a powerful tool that can build a versatile system to handle drives.

On top of all of that you'll find the usual great array of tutorials and reviews, as well as news, analysis, and commentary. Whether you're looking to see if Nvidia's latest graphics card, the GeForce GTX 1650, is worth picking up, or want to check out the latest M.2 SSD from Western Digital, we've got you covered. I hope you enjoy the issue!

Alan Dexter is Maximum PC's *executive editor and a punisher of hardware. He's been a tech journalist for over 20 years, and has no problem upsetting the PC industry as a whole.*

↘ submit your questions to: comments@maximumpc.com

THE NEWS

Zen 2 Is Imminent

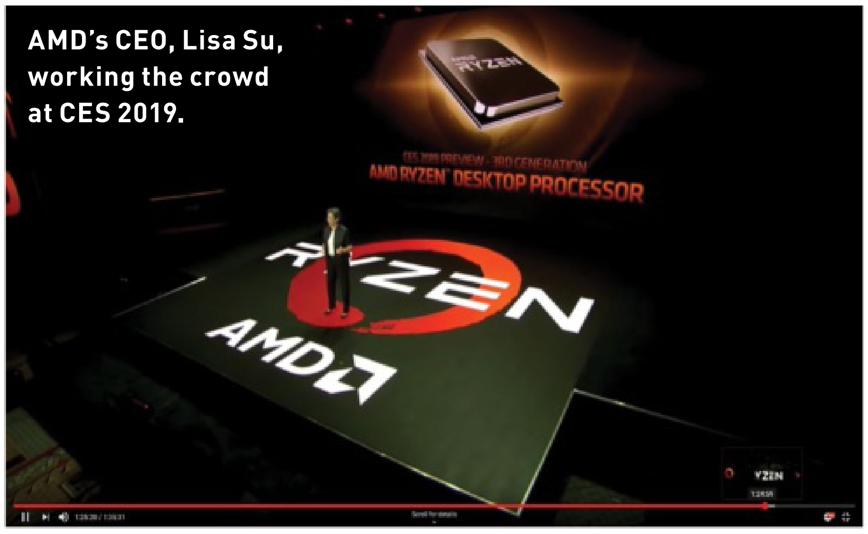
AMD turns 50, and Team Red is still looking good

AMD IS 50 YEARS OLD, and to celebrate, it launched a Gold Edition processor signed by CEO Lisa Su, and threw in some free games with its Radeon cards. It has good cause to celebrate, too: Things are looking particularly rosy as it gets ready to hit the market with its Ryzen 3000 series processors, featuring the new 7nm Zen 2 microarchitecture. AMD has produced some outstanding processors in the past (remember when the Athlon hit 1GHz?), but has never managed to fully exploit its innovation in follow-up designs. No longer: Buoyant with cash from selling server chips, AMD has been productive, and it looks like it is finally going to follow one very capable chip design with another, and in short order.

At CES 2019, we were treated to an eight-core engineering sample of the Ryzen 3000 used in anger, running against an Intel Core i9-9900K, which it proceeded to beat in Cinebench; admittedly only by 2,057 to 2,040, but enough to make a point. The power consumption was impressive, too: about 30 percent less than the i9-9900. Some speculated that it had been held back a little to highlight the lower power consumption.

Ryzen 3000 has a new manufacturing approach using a modular chiplet design (Intel has something similar). The main 7nm CPU die (called Core Complex, or CCX) is separate from the 14nm I/O die. This modular design is flexible, and improves yields. It also leaves enough room on the chip for two processor dies, each containing eight cores, so a 16-core desktop chip is due. AMD hasn't confirmed this yet, but has hinted that you "might expect that we will have more that eight cores."

A new microarchitecture should mean IPC (instruction per cycle) gains—it's been reported that we can expect a bump of 12–15 percent, according to engineering samples currently with mobo manufacturers. Others have been less optimistic, putting it at 5–10 percent for more general use. Either way, it's more than the jump between the original Zen and Zen+. Clock speeds? Good for a boost of 4.5GHz or more across the range, apparently. What is unlikely is speeds over 5GHz, certainly at first. There are various complicated reasons for this. The processing power bump comes largely from running more cores, and increasing the IPC. Memory bus frequencies run to DDR4-5000, beyond the Infinity Fabric abilities, so AMD has added a divider mode, which runs the IF at half the memory speeds. We shall see what overclocking this can unlock.



AMD's CEO, Lisa Su, working the crowd at CES 2019.

Ryzen 3000 CPUs are socket compatible with existing AM4 motherboards, given a BIOS update. AMD has stated it will continue with AM4 compatibility for all the range until 2020. However, B350 boards don't appear to have been included in that promise. If you do want one, there's a new accompanying X570 chipset. Zen 2 also introduces us to PCIe 4.0 in mainstream processors, which has double the bandwidth of PCIe 3.0, although older motherboards might not manage this apart from on the first slot. It offers a lot of bandwidth, most of which you won't need for now, although it opens the doors to some properly fast solid-state memory storage to come.

AMD's Radeon division has been busy, too, with 7nm Navi, its next-generation GPU microarchitecture. Details are currently sketchy, though. It'll surface in mid-market cards first; "enthusiast" versions aren't expected until next year.

Ryzen 3000, the second-generation EPYC server chips (called Rome, and more important to AMD's future than the desktop chips), and Navi are all on track to be available this fall. It is going to be another good year for processors, as Blue and Red square off. AMD has long offered good value for money, but one crown remains to be claimed: the fastest single-thread gaming chip. If AMD can come close to claiming this title from Intel, it will be something of a revolution: Intel has held that honor for so long. Ryzen and Zen put AMD back in the game two years ago, and Zen 2 will keep it there for a good while yet. **–CL**

> “
> AMD looks like it is going to follow one very capable chip design with another.

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GOOGLE'S ANNUAL SHOW-AND-TELL

I/O 2019 conference highlights

GOOGLE HAS JUST HELD its annual I/O event, and the biggest draw was the third beta for Android Q. This adds support for 5G, folding phones (if you can find one), revamped privacy settings, News story timelines, and a Focus Mode to silence notifications, among other frills. One interesting feature is Live caption, which uses AI to turn any audio into text. All the translation is done locally, so Google servers don't know what you are up to. Yes, there was a fair bit of talk about privacy, too. Google incognito mode is to be expanded to Google Maps, so you can keep your comings and goings private. You'll also be able to set Google to delete all your activity after three months. Google Duplex got another airing, now heading for the web, too. It was demonstrated filling out an online form. Still slightly spooky.

Among all the talk of better AI and voice control, there was some actual hardware, including new Pixel 3a and 3a XL smartphones. Google first dipped its toes into the phone market with its Pixel brand three years ago, but it's been struggling. The Pixel 3 has not sold well at all. The new phones are significantly cheaper: $399 and $479 respectively. It's a start, but if Google is serious about selling smartphones, it needs decent distribution. Currently, Google's only real carrier in the US is Verizon. Meanwhile, there are some good deals on the original Pixel 3. A more successful piece of hardware for Google has been the Home Hub range, which has now been rebranded as Google Nest (no, we have no idea why either). The prices have dropped here, too: The Nest Hub (Home Hub as was) is now $129. A new Nest Hub Max is to follow, at $229, with a larger 10-inch screen, plus a camera, which enables such clever features as halting music playback by holding your palm to the lens. Smart. **–CL**

DELL LAPTOPS COMPROMISED

SUPPORT ASSISTANT LEAVES DOOR OPEN

DELL HAS SHIPPED million of systems bundled with its SupportAssist software. This remote support tool is there to fix things, but it has a nasty security flaw that could leave your machine open to attack. The vulnerability is a remote code execution, triggered by a visit to a compromised website, where Java scripts can get to work, and potentially install anything on your machine, from ransomware to mining bots.

To work, the hacker needs to be on the same local network, but the wide use of Wi-Fi makes this easier than you might think. Patches have been issued, but not everybody takes notice of endless software patches. The hole was discovered last October, worryingly easily. As ever, we learn about it only when patches are being rolled out. It took Dell a week to confirm the problem, but over five months to fix it. **–CL**

SAMSUNG'S FOLDING FAILURE

Galaxy Fold is pulled from sale indefinitely

SAMSUNG'S GALAXY FOLD made it to a few reviewers before it became clear the company had blundered: The screens broke in droves. Launch events were canceled, and deliveries halted. Customers are now being asked to opt in to keep their orders active. The phone is being "enhanced," which presumably means being fixed. It's a pity, because when it worked, it worked well. There are no clues as to when the phone will reappear.

What went wrong is unclear, but iFixit posted a teardown of a Galaxy Fold, and called it "alarmingly fragile." This didn't go down well at Samsung, which applied pressure in the right places to get the article pulled. Apparently, the screen is delicate, and gaps in the casing allow dirt to get underneath, causing it to crack when flexed. The Galaxy Fold gives every impression of being rushed to market, despite claims of years in development. **–CL**

Tech Triumphs and Tragedies

A monthly snapshot of what's good and bad in tech

TRIUMPHS

✓ **MOST POWERFUL LASER**
10 billion million watts, and able to vaporize matter: part of the International Extreme Light Infrastructure, 10 times the quoted power of the Death Star.

✓ **DETAILED UNIVERSE PIC**
7,500 Hubble images have been stitched together to make a pic that includes 265,000 galaxies.

✓ **SUPER SUPERCOMPUTER**
Oak Ridge Lab to house Frontier, 50 times faster than the current top machines, at 1.5 exaflops.

TRAGEDIES

✗ **WHATSAPP SPIES ON YOU**
Hackers got into the app just by calling your phone—you didn't even need to respond.

✗ **ANOTHER BITCOIN HEIST**
Binance was hit by hackers who got away with 7,000 coins worth $41 million from its hot wallet.

✗ **DRAGON II EXPLODES**
Smoke was visible for miles, but it took a while for SpaceX to come clean. A capsule was completely destroyed on the launch pad during testing.

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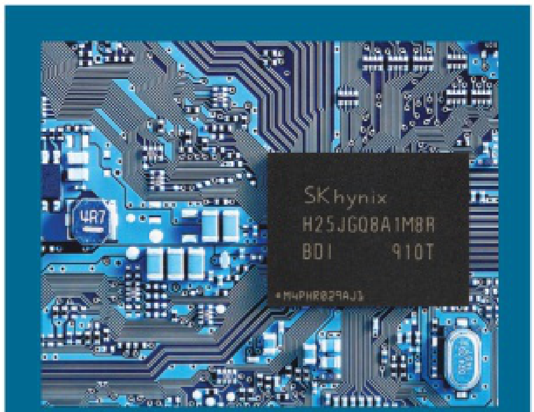
Facebook Faces Fine

FACEBOOK HAS HELD ITS ANNUAL F8 Developer's Conference, where it unveiled its plans for a fresh new look, code name: FB5. The redesign promises to be less cluttered, easier to navigate, and with more emphasis on Workplace chat and groups. All well and good, but the hot potato is privacy. In Zuckerberg's opening address, he claimed that "the future is private," and "We don't have the strongest reputation on privacy right now, to put it lightly, but I'm committed to doing this well, and to starting a new chapter for our products." Actual details were thin on the ground, although there was talk of restricting data requests by third parties, and encrypting data by default. Facebook may not be able to read your messages, but it'll still be able to build a comprehensive data profile on you—that is, after all, its core business.

The last year hasn't been the smoothest for Facebook. The mounting criticism over privacy blunders and an investigation by the Federal Trade Commission are coming to a head. There is going to be a fine, and it is expected to break records. This unenviable record is currently held by Google, which shelled out $22.5 million in 2012. Facebook is looking at something in the $3–5 billion range. This dates back to a promise in 2011 to get permission from its users to share data with third parties, which the FTC says Facebook has broken. A couple of senators have gone as far as urging the FTC to make Mr. Zuckerberg personally responsible for privacy violations—an unlikely event. As well as the fine, Facebook looks likely to face many years of FTC monitoring. Luckily, the company has a mountain of cash, earnings are buoyant, and news of the size of the impending fine didn't dent the stock price one bit. Facebook is still hugely popular—and profitable. We may not trust it as much as before, but we don't appear to be deleting it either. **–CL**



SK Hynix Goes 96-Layer

SK Hynix has started sampling its long-awaited 96-layer 1Tb QLC NAND flash memory chips. QLC stands for quadruple level cell—four bits of data per cell. The result is 10 percent smaller than the previous triple level cells. They will appear first in enterprise servers; the company is talking of drives of 16TB or larger. Toshiba also has a four-cell 96-layer chip, which will be with OEMs shortly. Intel is expected to make a similar foray into 96-layer later this year.

This year, the PC market for old-school hard drives is on track to be half what it was in 2018. SSD prices, meanwhile, are falling by 50 percent year on year, with a 1TB SSD expected to be mainstream this year, at under $100. Things are due to get even more interesting when PCIe 4.0 lands. **–CL**

SuperMicro Leaves China

Last fall, a bizarre and worrying story emerged about alleged "spy" chips embedded into SuperMicro server motherboards made in China. Then things went quiet, the original source for the story (Bloomberg) stuck by it, SuperMicro denied it, and its own audit found no evidence of tampering. However, customers were spooked, and sales dropped, especially in the US, where SuperMicro makes 60 percent of its revenue. The company has now asked suppliers to move production out of China, while it expands its own production facilities, including a new factory in Taiwan. Spy chips or not, customers were asking for non-Chinese boards. In 2017, about 90 percent of server boards were made in China; that figure is now around 50 percent. Whether or not there is any truth to the allegation, people are taking it seriously. **–CL**

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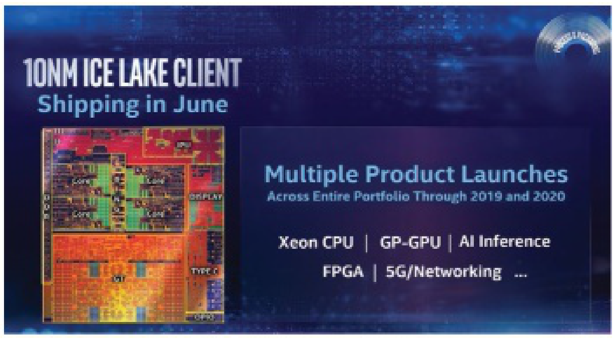
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INTEL'S ROCKY ROAD MAP

Delays bedevil 10nm and 7nm chips

WHEN AMD HAS something big in the pipeline, Intel always manages to seem busy, too. In the last month, we've had a slew of launches and announcements: 7nm chips are go for 2021—it's official—which sounds like good news, but isn't. Intel is lagging. There have been huge problems getting its 10nm chips going, which were to fill the gap. So much so that there have been rumors that Cannon Lake has been shelved, which Intel denies.

Part of the problem is that Intel has traditionally tied new microarchitecture designs to die shrinks, which has left it producing numerous iterations of 14nm designs when the shrink stalled. From now on, it plans to design architectures that are portable between die sizes. The first of these is Sunny Cove, and we have just had our first proper look at a block diagram of this in the Ice Lake chips at their launch at CES. This should be taking on Zen 2. Intel promises twice the graphics performance, 2.5–3.5 times the AI performance, and three times the wireless speeds of Coffee Lake. We'll also get to see Intel's Gen11 integrated graphics, which should be good: It's the first fruit from its hiring of ex-Radeon architect Raja Koduri.

The first chips won't be desktop chips, but laptop parts; the desktop version could be pushed back to 2021. Mapped out beyond Ice Lake is Willow Cove, with improved cache, security, and other optimizations, due in 2020. These popped up in a leaked road map for 2020 featuring Tiger Lake chips, again mobile.

Intel has also fleshed out its 9th Gen 14nm Coffee Lake chips, with tweaks such as better thermal handling, more cores, and improved memory support. But supply issues continue to bite. This won't be the last gasp for Skylake: Comet Lake is still to come. These 14nm, 10th Gen chips are due late this year, or early next, and are expected to squeeze 10 cores into a space originally housing four. **–CL**

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TECH TALK

Intel in Battle Between Performance and Security

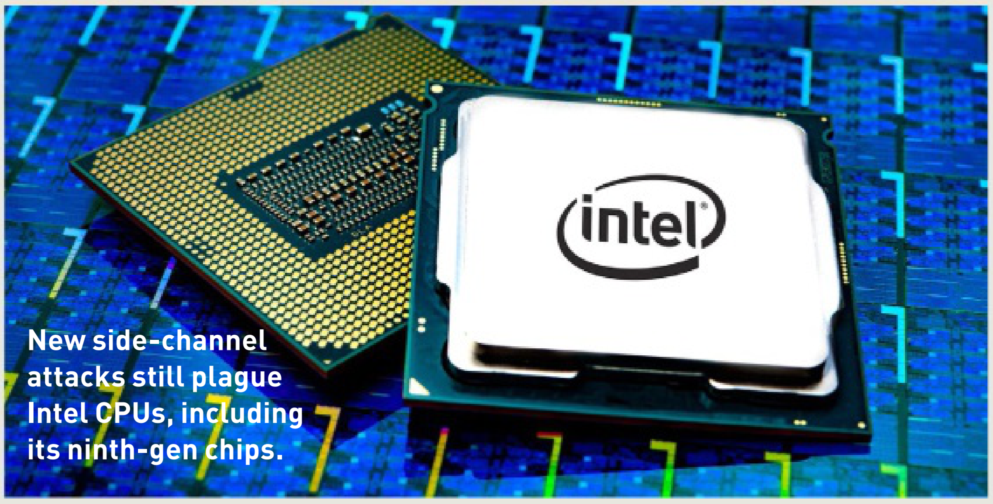
THE PAST TWO YEARS have been rough on Intel CPUs. As if AMD's sudden increased competitiveness with Ryzen and the repeated delays of Intel's 10nm process weren't enough, security researchers continue to find new and interesting ways to compromise systems via side-channel attacks.

It started with Meltdown and Spectre in early 2018, but those were just the tip of the iceberg. Since then, numerous other exploits have been discovered, with the latest MDS attacks (Microarchitectural Data Sampling) of RIDL and Fallout affecting Intel CPUs as far back as the first-gen Core i7 parts.

Patches and mitigations have mostly addressed the problems, but performance has taken a hit in some workloads. And we're likely to continue seeing similar exploits—not just for Intel CPUs.

Where do these exploits come from, and how could these vulnerabilities go undiscovered for so long? It's a complex subject, and the difficulty is that these side-channel attacks don't go after data directly, using other methods to "trick" CPUs into divulging secrets. These attacks use knowledge of low-level CPU features that help processors run faster. Intel—and other processor companies, including AMD and Nvidia—are stuck fighting a battle between performance and security, with users caught in the crossfire. Here's a very quick rundown of some of the exploits so far.

- **Meltdown:** Caches are a great way to speed up CPUs, by avoiding delays accessing slow DRAM or hard drives. Meltdown used a cache timing attack to access protected data. The KPTI fixes applied at the OS level help prevent this form of attack.
- **Spectre:** Every time a branch occurs in code, a CPU has to guess where the next instructions will come from. It "speculates" and starts executing those instructions, so that all the hardware isn't just twiddling its thumbs. Spectre uses knowledge of branch prediction and speculative execution to get at protected data.
- **RIDL, MDS:** CPUs break the work for each machine instruction into 20-30 stages. To make all these stages work together, CPUs have lots of buffers to hold data, so everything can run as fast as possible. MDS-class attacks can use the buffers to leak data.
- **Fallout, MDS:** Finding six independent instructions per clock to dispatch is hard. Hyper-Threading (or Simultaneous Multi-Threading) allows two instruction threads to run concurrently on the same core, sharing some resources. Finding three independent instructions from each thread is easier, leading to better use of resources and potentially improving performance. Fallout and other MDS attacks are easier to implement with Hyper-Threading.



New side-channel attacks still plague Intel CPUs, including its ninth-gen chips.

© INTEL

For decades, CPU designs have focused on making processors faster and more efficient, but the clever speed hacks leave potential vulnerabilities. The complexity of carrying out a side-channel attack is high, but it only takes one functioning solution to pave the way for many clones. With multiple proof of concept exploits, there's a ripple effect where new approaches are also bearing fruit. It's forcing CPU architects to go back and re-examine everything that's done to ensure there are no critical flaws and exploits.

There's no simple solution. Software mitigations can only go so far—we need new CPU designs built with security in mind. But that security may come at the cost of performance. Otherwise we may end up in a dystopian future where our data is increasingly vulnerable. Assuming we're not already there.

Jarred Walton has been a PC and gaming enthusiast for over 30 years.

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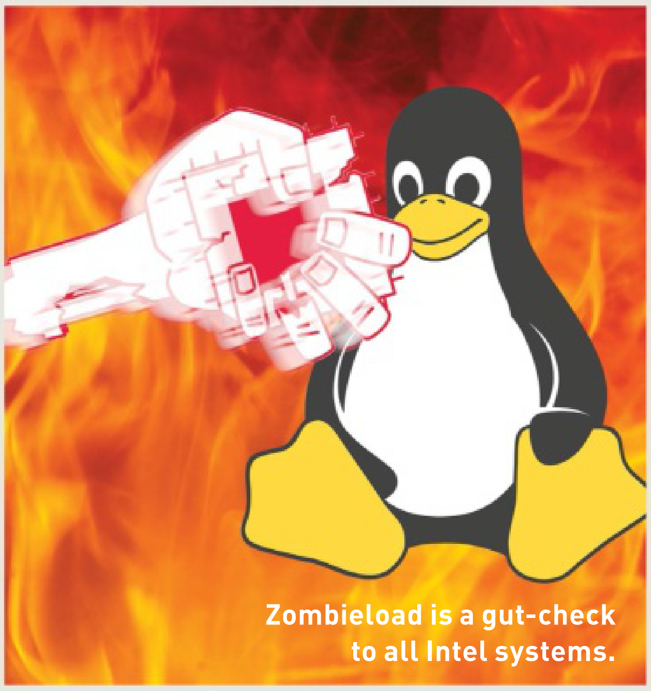
Alex Campbell

OPEN SOURCE

The Required Kernel Upgrade



Zombieload is a gut-check to all Intel systems.

I SPOKE TO WES at sister mag *PC Gamer* via Twitter about a month ago. He asked if he should update the kernel on his home server. I said that for most people, running the kernel that comes with your distro (with regular updates) is generally fine.

In the light of Zombieload, however, I'd caution users to really look at what kernel they're running, and upgrade or change it if necessary. The name sounds like the title out of a bad horror movie, but once you figure out what it can do, it feels scary as hell to know such a thing was even possible.

First things first: If you haven't updated your kernel on your Linux machines yet, go do so right now. At time of writing, the 4.9, 4.14, 4.19, 5.0, and 5.1 branches of Linux kernel have been updated with patches and backports to mitigate risk from the Zombieload vulnerability. If you are not on one of those branches, I recommend switching to a currently developed kernel, or check your distribution for any backports they may have coming down the pipe.

If you're wondering if you should be scared, the answer is "probably yes." Zombieload is a hell of an exploit, because it doesn't have anything to do with the kernels of Windows, Linux, or MacOS, but rather with the architecture of Intel's CPUs, and how Hyper-Threading is implemented. And it affects every Intel CPU made since 2011. (Somewhere on the Internet, a forum full of Team Red fans is bathing in the warm glow of Schadenfreude.)

Basically, Hyper-Threading CPUs find speedups by executing multiple branches of code in advance of the actual branch evaluation. If that doesn't make sense, just imagine that it's your friend's birthday, and you want to bake them a cake. You know that they will either want devil's food or angel's food cake, but you'll have to wait a half an hour until they get off work before they can tell you what they want. So, being the intrepid and loving friend you are, you bake both, and simply throw out the one that isn't needed after your friend calls. This process is called speculative execution, and it's part of why Intel Hyper-Threading CPUs are so heckin' fast. It's also their Achilles heel.

> Zombieload is an example of why you shouldn't just run any script you find on the Internet.

What Zombieload does is look at the cache that stores the results of the speculative execution results, and uses that information to read keystrokes, screens, or really just about everything. This should really worry multi-tenant systems and providers that offer virtual machines in the cloud, because code that uses the Zombieload exploit could be used to see anything that's running on the same physical machine, even if it's walled behind another VM.

The upshot to this is that for many personal-use Linux PCs, it is relatively unlikely that you'll run such code, so long as you stick to trusted and signed packages from your distribution's software repository. However, if you're running an untrusted tool you find in a link on a website or a random git repo, you could be at risk. While Linux is generally more secure than Windows, exploits like Zombieload are a great example of why you shouldn't just run any script you find on the Internet. If you don't understand what a script's or program's code does, keep your software search within the confines of your distro's repository. (TLC's "Waterfalls" comes to mind.)

And again, if you haven't thought about upgrading your kernel in a while, now is the time to do it. If you're on a kernel that isn't getting a backported patch, you need to switch to a supported kernel pronto. If you're unsure about what kernel you're using, you can check it with the console command `uname -r`. As of time of writing, the current patched versions of the Linux kernel are 4.9.176, 4.14.119, 4.19.43, 5.0.16, and 5.1.2.

Alex Campbell is a Linux geek who enjoys learning about computer security.

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THE LIST

BEST BUDGET GPUS RIGHT NOW

8

GEFORCE GTX 1650 4GB

The newest card on this list, the GTX 1650 is a cheap, serviceable, low-end gaming processor.

7

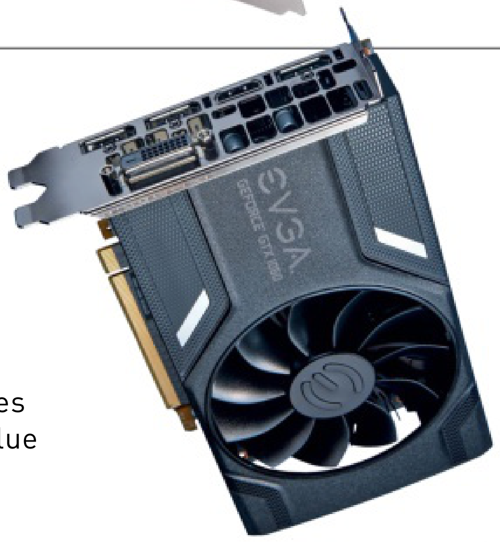
GEFORCE GTX 1050 Ti 4GB

The 1050 Ti won't crack 1080p ultra in most games, but with a bit of tweaking, it can still hit 60fps.

6

GEFORCE GTX 1060 3GB

The 3GB model of the GTX 1060 isn't magical, but provides some of the best value for money around.



5

RADEON RX 580 8GB One of the best Radeon GPUs—but the 590 provides greater speeds for only a marginally higher cost.

4

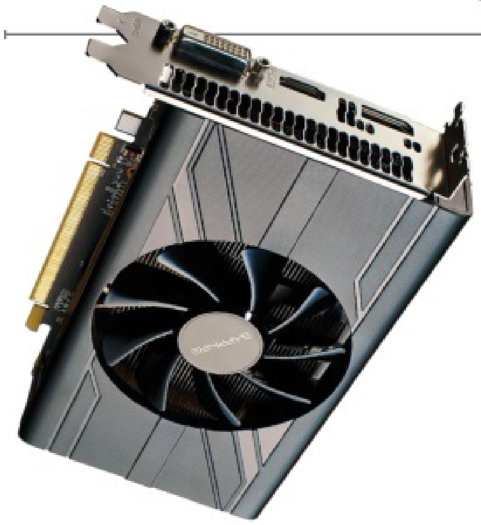
GEFORCE GTX 1660 6GB

The first of Nvidia's 16 series, the 1660 is barely a budget card, but it runs well.

3

GEFORCE GTX 1060 6GB

The big brother of the two 1060 cards, the 6GB version packs more punch for its price.



2

RADEON RX 570 8GB

Solid, reliable, inexpensive; AMD's 570 provides some of the best price-to-FPS value around.

1

RADEON RX 590 8GB This is it: a godly 1080p gaming GPU for under $250. Our recommendation would be a Sapphire Nitro model.

GEFORCE GTX 1650 4GB © MSI.COM. GEFORCE GTX 1050 TI 4GB © GIGABYTE

HEAD TO

BY **JEREMY LAIRD**

Air Cooling vs. All-In-One vs. Custom Loop Water Cooling

High-performance computing is all about keeping cool. But what's the best way to achieve that? Air cooling is the default, while water cooling is often seen as the gateway to maximizing performance. But is that true? What's more, if you're considering water cooling, are pre-built AIO (all-in-one) coolers the best bet? Or can you get better performance from a custom closed-loop solution? Of course, performance may not be your only consideration. Ease of use, longevity, and even looks might be on your radar. Time to find out how to keep cool.

ROUND 1

Looks

There are some pretty nifty looking air coolers. Big, bold coolers with hefty heatsinks, oversized fans, and more LEDs than you can shake a SATA cable at. Heck, you can even get air coolers with programmable LEDs that you can sync with other elements of your build, such as case lighting, keyboards, and mice. Air coolers that make a visual statement? Not a problem.

But for sheer visual clout with a sci-fi vibe, nothing competes with a slick custom closed-loop water-cooling installation. What's not to like about gleaming pipes full of brightly colored coolant? Of course, much depends on your specific implementation. A really great-looking custom water-cooling install is costly and complex. Moreover, a shonky build won't just look cheap, it could be a recipe for disaster.

As for AIO coolers, you might think they don't stand a chance from a pure styling perspective. After all, most are at best functional—even agricultural—looking items. Typically, you're looking at large black radiator, a couple of rubber hoses, and the CPU bracket. Not exactly sexy. On the other hand, if neat and tidy is your aim, AIOs can deliver a really nice no-nonsense solution.

Winner:
Custom Loop Water Cooling

ROUND 2

Value

With high-performance PCs, the law of diminishing returns tends to apply. The more you spend, the less you get in terms of performance uplifts. CPUs are a class example. Intel will sell you a very nice six-core chip for well under half the cost of some of its eight-core models. The latter are faster, but not enough to justify the price premium.

The same applies to cooling. The best bang-for-buck is something like a $20 air cooler. Sure, it won't enable the kind of clock speeds that more expensive solutions unlock. If you care about maintaining the lowest possible temps, you need something pricier, too. But for virtually no cash, you get better performance than the likes of a standard Intel cooler can provide. And even compared to the most expensive cooling kit, the computing experience is indistinguishable much of the time.

That said, AIO solutions are very affordable. $50 buys you a single-fan solution from one of the bigger brands. And, it's a component you can typically use for multiple builds. So, it's a worthwhile long-term investment. As for custom water cooling, going cheap is a scary prospect for PC reliability, so the value proposition is simply poor.

Winner:
Air

ROUND 3

Installation

Air cooling seems like the simplest solution when it comes to installation. Most coolers are compatible with a range of modern CPU sockets, so at most it's a case of choosing the right bracket, maybe fitting that bracket, slapping on some heat paste, then bolting everything down.

The exception comes with larger and more aggressive coolers. For starters, big coolers that spread out from the socket can come into conflict with the RAM sockets. Broader compatibility with cases can also be an issue.

All-in-ones rarely present problems regarding motherboard components. So, it largely comes down to case compatibility. However, most AIOs conform to standardized 120mm and 240mm form factors that are provided for by pretty much any decent case. The exception to that is some small form factor cases, which can limit your options for using AIO solutions.

As for custom water-cooling loops, they're by far the most difficult to install. In theory, their configurability and scope for customization allows for a wide range of compatibility. In practice, however, it can be both hard work and a little hit and miss.

Winner:
Tie: Air and All-In-One

HEAD

Left to right: Air cooling delivers decent performance for little cash. AIOs are more affordable than ever. Custom water cooling offers most potential, but is complex and costly.

noctua
NF-A12x25 PWM
CORSAIR
CoolStream CE
Mayhems
Aurora
PHANTEKS

ROUND 4

Longevity and Maintenance

For simple, worry-free operation over the long haul, air cooling is a great option. Worst case scenario: You'll want to whip the cooler out once a year and give it a thorough clean to remove dust and restore full cooling efficiency.

Given the relative complexity of an AIO cooler, you might assume high maintenance levels, but that isn't necessarily so. They're designed to be much lower maintenance than custom water cooling. They're pre-filled and sealed from the factory, with no need to refill, flush, or monitor levels. In that sense, maintenance levels match that of an air cooler. You just need to dust off the radiator now and then. Reliability over the long haul, however, is more questionable. With both fans and a pump, there's more to go wrong.

As for custom water cooling, forget it—it's far higher maintenance. Levels have to be checked, and the system may need topping up. Full-on disassembly for flushing and cleaning may also be necessary; in fact, it's recommended. Likewise, with far more parts, many of them user-assembled, there's way more to go wrong. If you want an easy life and perfect long-term reliability, don't go with a custom water loop.

Winner:
Air (by a whiff)

ROUND 5

Performance

Air cooling might deliver the best bang for your buck, but it isn't the most effective cooling solution on offer. That's water cooling. But does AIO or a custom loop perform best?

You might think there's little in it. Both pump water through a CPU block that offers the same contact with the CPU's heat spreader, right? Yes, but flow rate makes a difference, as does radiator size and efficiency, the fans attached to it, and all that jazz.

Most AIOs fall into two categories: 120mm models with a single fan, and 240mm items with dual fans (triple-fan models are also available). There's some variation in design and efficiency, but they're largely known quantities with predictable performance. Custom loops are a whole different ball game.

In theory, there's no limit to how much water you can pump or the size and number of radiators and fans. At the very top end, then, custom cooling offers the most potential. You can specify more powerful pumps, larger radiators, and more fans. Actually achieving better cooling performance versus a quality AIO cooler, of course, will depend on getting your design, implementation, and installation right.

Winner:
Custom Loop Water Cooling

And the Winner Is...

Spotting the victor in our head-to-heads is usually pretty easy. A quick scan of the category winners makes it obvious enough. But not this time. The all-in-one water-cooling solution didn't take a single category outright, yet it's our pick of the three options.

That's because it's a very strong all-around solution. It's not the cheapest, but it remains affordable, especially if you consider that a good AIO kit should last long enough for multiple PC builds. What's $50 to $100 over a couple of builds? Exactly.

AIO coolers are also dead easy to use. They're compatible with virtually all motherboards, the vast majority of PC cases support them, and they're a cinch to install. They also provide cooling performance that only a really complex and costly custom-loop water-cooling kit would exceed.

In fact, the only area where AIOs are unambiguously off the pace is in terms of visual bling. But if you prefer a low-key and functional look, or you don't care about that aspect, an AIO is now the obvious all-around choice for performance PC enthusiasts.

DOCTOR

THIS MONTH THE DOCTOR TACKLES...

> HDMI Crash Course
> Movie Magic
> Missing Gigahertz

HDMI Issues

I've had this problem for about seven years now, but I've managed to work around the issue until recently. In short, I am using a Palit GeForce GTX 460 graphics card that suffers from occasional screen flickers, followed by a message saying that the video driver crashed and recovered. Other times, Windows blue-screens and must be restarted. I have tried everything on the software side, including reinstalling drivers and cleaning out the previously installed drivers.

By pure luck and coincidence, I noticed that the issue was solved by connecting a second monitor, giving me one display attached via HDMI and another hooked up to the VGA output. So long as I keep both monitors plugged in, Windows doesn't report any errors. The problem only resurfaces if I use the HDMI port exclusively.

Because of its age, I recently moved the video card to a spare PC, and I'd like to avoid having a second monitor hooked up due to space constraints. Do you have any other idea how to resolve what I'm seeing? I should be allowed to use just one monitor, right?

–Louie Tan

THE DOCTOR RESPONDS: The Doc has never encountered these exact symptoms, but he'd suggest some general troubleshooting steps to narrow down the cause of your unstable HDMI signal.

First, update any software elements that might yield quick and easy fixes. Is your motherboard's BIOS current? Have you applied all the available patches for Windows? You mentioned removing your drivers and applying new ones, but if you only used Nvidia's uninstall routine, try downloading Display Driver Uninstaller (DDU), start up in Safe Mode, and run the utility to completely clean out old remnants of previous drivers. Then, grab the latest build for your GeForce GTX 460, which appears to be 391.35.

If the problem persists, start eliminating hardware variables. Have you tried a different HDMI cable? How about the HDMI input on a different monitor, to eliminate that? Do you have access to a spare graphics card you could swap in temporarily? Does your existing display have another input you could use aside from HDMI? If not, is an adapter viable? Also, make sure the GeForce isn't overheating by monitoring its temperature with FurMark.

Given your GTX 460's age, it might simply be damaged. Consider replacing it with an entry-level GeForce GT 1030, which would be even faster.

intel
9TH GEN
CORE i9
UNLOCKED

Intel's i9-9900K is an eight-core beast, with 5GHz boost.

© INTEL

Long File Paths

I read your response to Tom Adams regarding removing the 260-character limit for a file's path and name in your March 2019 edition. It's about time! I even found a Microsoft article that explains this in detail. According to that, "Starting in Windows 10, version 1607, MAX_PATH limitations have been removed from common Win32 file and directory functions. However, you must opt in to the new behavior."

So, why can't I get it working? I have Windows 10 Pro 1803. I used GPEdit and enabled the proper setting. I assume that the hard drive needs to be formatted with an NTFS partition. I tried creating a path longer than 260 characters on my C: drive and an external drive, but I couldn't. I tried this on two computers. What am I doing wrong? **–Leon Garfield**

THE DOCTOR RESPONDS: Enabling long path behavior in Windows doesn't automatically make every Windows-based application aware of this new capability, unfortunately. In the Microsoft article you're looking at, the company clarifies, "The shell and the file system have different requirements. It is possible to create a path with the Windows API that the shell user interface is not able to interpret properly."

The Doc was able to confirm on multiple PCs in his lab that Microsoft's own File Explorer won't allow you to create a longer path, even after toggling on LongPathsEnabled in the registry. However, he was able to move and copy files

↘ submit your questions to: doctor@maximumpc.com and folders with very long paths. And although renaming files didn't work natively, a utility called Long Path Fixer allowed him to change files that File Explorer couldn't.

Copying VHS Movies

Hi Doc. Our VCR died, and I realized that the time for VHS/VCRs may be ending soon. Should I look for a used VCR and DVD recorder, or is there another direction you recommend? **–Mitch Stanley**

THE DOCTOR RESPONDS: The Doc sees four viable options. One: Roll the dice on a used/refurbished VCR and go back to watching VHS cassettes as before. Two: Buy a VCR and an analog-to-digital capture device, enabling you to convert old home videos into a format you can burn to a DVD. Three: Track down a combination VCR/DVD recorder that can be used to archive your VHS tapes using a single device. Four: Send your cassettes to a service like Costco, Walmart, or Walgreens to digitize them for you. Simply replacing your VCR is only going to land you in the same spot at some point down the road, and those tapes aren't getting any younger. So, let's limit our discussion to the second, third, and fourth paths.

Doing it yourself makes sense if you have an appetite for risk, the patience to master old, unsupported technology, and time to babysit an analog process—one hour of footage takes one hour to convert. You can find used/refurbished VCRs between $60 and $80. Just be ready to accept that some work great and others are lemons. At least try to find a seller willing to guarantee your purchase for 30 days or more. Next, you need a capture device like Diamond's $40 VC500, which converts the analog signal into an MPEG file. Bundled CyberLink PowerDirector software gives you the power to make edits before burning movies to DVD.

A VCR/DVD recorder integrates all the functionality you need for digitizing old videos without a PC, and you might even find an unused one. But they're a lot more expensive. Unless you have a lot of content to convert, the cost might not be worthwhile.

If you only have a handful of cassettes worth preserving, paying a service might make the most sense. Costco charges $20 to digitize up to two tapes, for a maximum of two hours. Although the Doc is big on DIY, he sees little reason to gamble on a 20 or 30-year-old electromechanical device unless you're archiving a substantial library of material.

Is AMD Vulnerable?

Hi, Doc. Could you please explain the security vulnerabilities of AMD CPUs, just like you did for Intel's chips in the March 2019 issue on page 23? **–Peter Sweeney**

THE DOCTOR RESPONDS: According to AMD, its architectures are affected by the Google Project Zero Variant 1 and Variant 2 vulnerabilities, referred to as Spectre, but not Variant 3, known as Meltdown. The company says mitigations take the form of operating system and microcode updates covering platforms as far back as the original Bulldozer.

Specifically, Variant 1 was addressed by Windows and Linux patches last year. AMD claims Variant 2 is especially difficult to exploit on its processors, but released recommended mitigations anyway. Unfortunately, the responsibility for implementing some of those updates falls on motherboard manufacturers with BIOS teams that are already spread too thin. In a random sample covering different vendors, boards, chipsets, and sockets, there were disturbingly few updates to platforms predating Socket AM4.

If you want to convert old VHS tapes to DVD, a capture device like Diamond's VC500 is an affordable solution.

© DIAMONDMM.COM

The Speculative Store Bypass vulnerability, aka Variant 4, was mitigated through operating system updates. Again, though, AMD insists this one is especially difficult to exploit. The L1 Terminal Fault vulnerability addressed by Intel through firmware purportedly does not affect AMD at all. Toward the end of last year, the company published a statement claiming that its hardware paging architecture protected against attack.

When the smoke cleared, AMD's underlying CPU design appeared more resilient than Intel's. At the same time, older AMD platforms seemed less likely to receive updates for the few vulnerabilities legitimately applicable to its architecture. On the bright side, upcoming Zen 2-based CPUs are expected to include in-silicon mitigations for Spectre and its derivatives, meaning performance-draining software patches won't be necessary.

Give Me 5GHz!

Hi Doc. I've Googled and I've hit Reddit, but I can't find a satisfactory answer to my question. Recently, I upgraded my Core i7-7700K to a Core i9-9900K for one reason: 5GHz. I figured it'd be easy to see that magical number in Windows using my Asus Z390 motherboard. However, it never happens. I get 3.6GHz if I don't touch the BIOS at all. When I do what the Internet tells me to do, the CPU gets up to 4.65GHz. But why the hell did I upgrade if I never get to see my processor at 5GHz?

Yes, I know that using an all-core 50x multiplier technically overclocks the chip to 5GHz. But shouldn't I be hitting this milestone without overclocking? I'm very confused by my expensive upgrade. Was I bamboozled on this one? Where are my gigahertz? **–Bobby Roberts**

THE DOCTOR RESPONDS: Before getting too despondent, the Core i9-9900K is an absolute beast. Compared to your Core i7, it boasts two times the cores, two times the cache, a 500MHz-higher peak Turbo Boost, hardware-based mitigations for some of last year's security vulnerabilities, and support for faster DDR4 data rates. That said, the Doc understands your frustration. Eight years have passed since he saw the first CPU with a 4GHz boost frequency, so 5GHz is a long time coming.

To start, make sure your motherboard's BIOS is up to date. You may even want to restore the factory defaults. Check to see what Asus MultiCore Enhancement is set to. The "Auto" setting imposes Asus's "optimized" ratios, often at the expense of power consumption, while "Disabled" falls back to Intel's default Turbo Boost ratios. Play with both to see how they compare.

Once you boot into Windows, open HWiNFO64's sensor status pane, which gives you current, minimum, maximum, and average values for each of the 9900K's cores. Run a single-threaded Cinebench benchmark and see what the hardware monitor reports. So long as you keep your workload limited to one or two cores, 5GHz should be attainable. If you don't see more than 3.6GHz, the 9900K's base clock rate, check to make sure Turbo Boost is turned on, and that the processor isn't getting too hot. Your issue sounds like something other than too many background processes running, eating into Turbo Bins.

UPGRADES

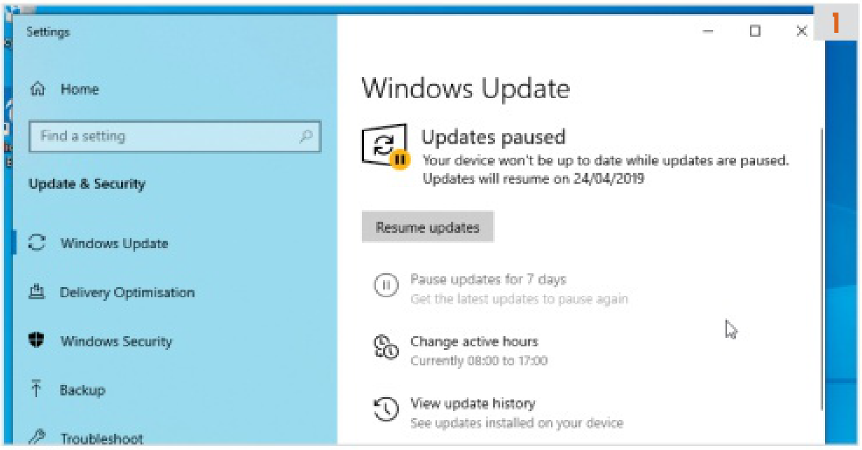
BY **NATE DRAKE**

Windows 10 May 2019 Update

May 2019's update will be the first major Windows 10 update this year. It appears to be all about making the interface less cluttered, more visually appealing, and more efficient. Microsoft has allocated set space for updates, streamlined the Start menu, decluttered the search bar, introduced a new-look desktop, enhanced app searches, and given Sticky Notes a new look. It has also introduced Windows Sandbox, so power users no longer have to install their own virtual machine when testing new programs.

1 Updates Can Now Be Paused

For users on the go or on a limited data allowance, Microsoft has introduced a feature to pause updates for a certain period of time. You can access this via "Windows Update." The default delay is seven days, but you can change this from "Advanced Options." While it's always advisable to keep your system up to date, upgrades can sometimes contain annoying bugs, forcing you to restore Windows from a previous backup. Using this new feature, you can hold fire for a few days until you're certain the update is free of flaws. When you reach the pause limit of seven days, your device will need to get new updates before it can be paused again.



Windows Update

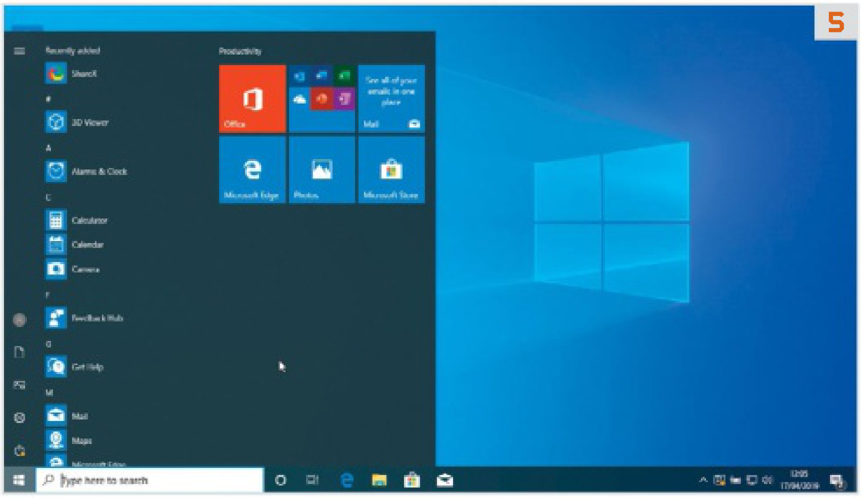
Updates paused
Your device won't be up to date while updates are paused.
Updates will resume on 24/04/2019

Resume updates

Pause updates for 7 days
Get the latest updates to pause again

Change active hours
Currently 08:00 to 17:00

View update history
See updates installed on your device



2 Reserved Space for Updates

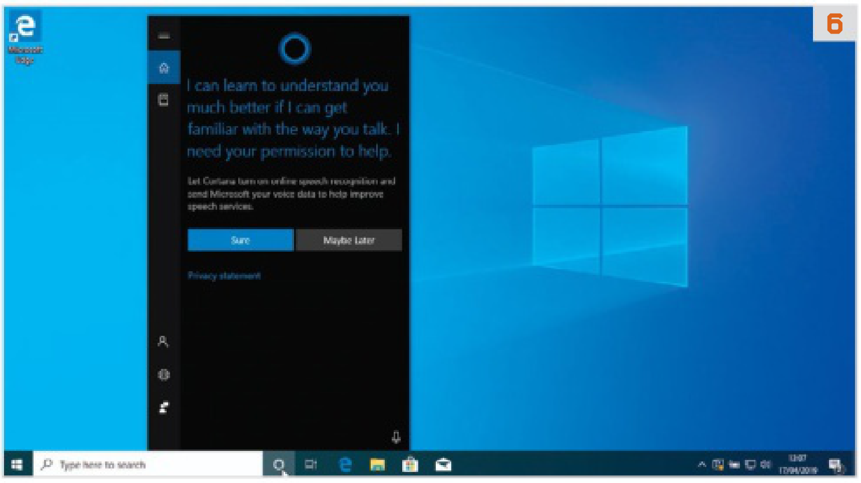
While some users may not be too happy about Microsoft allocating space, the new update ensures that 7GB of your hard drive is reserved for updates. Microsoft believes this makes the update process easier and more efficient. At the time of writing, the size of this allocated space can't be changed using the default Windows tools, but the good news is that 7GB is more than enough to accommodate even major upgrades. This means you'll never see an update fail due to lack of space, but the feature is unlikely to be popular with users of Windows 10 tablets, where storage is at a premium. Update files are temporary data, so can be removed automatically after each upgrade.

3 New Sign-In Features

The May 2019 update seems to be focused on decluttering many of the main areas of the Windows 10 desktop, such as Settings and the Start menu. The "Sign-in" section has been similarly overhauled. It's now much easier to choose your sign-in settings, making it far less cumbersome to log in. You can also now choose to sign in with a four-digit PIN code. If you choose to skip PIN setup, you can always go back to "Sign-in Options" and activate "PIN sign-in." Once your PIN is set up, you can revert to using a password at any time from the sign-in option screen. While this new feature is convenient, a strong alphanumeric password is much harder to break than a four-digit code.

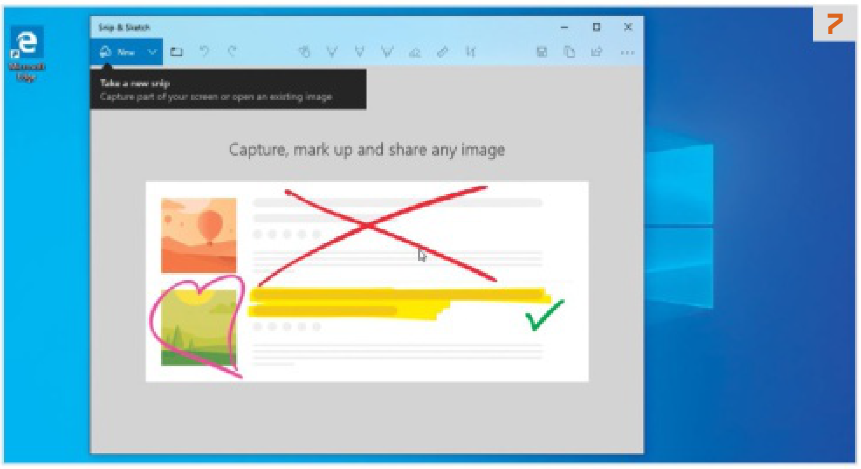
4 New Light Theme

Windows 10 had already introduced a dark theme for users in its previous updates. Microsoft has now introduced a "light" theme. The Start menu and taskbar can now be changed to white. While not directly related to the



I can learn to understand you much better if I can get familiar with the way you talk. I need your permission to help.

Let Cortana turn on online speech recognition and send Microsoft your voice data to help improve speech services.



Take a new snip

Capture part of your screen or open an existing image

Capture, mark up and share any image

"light" theme, the Windows 10 Home screen is now a much lighter shade of blue. The Windows 10 dark theme is also still available.

5 Clutter-Free Start Menu

The Windows 10 update comes with some very welcome improvements to the Start menu. When you first launch the Start menu after applying the May 2019 update, it appears much less cluttered than previous versions. Space is now used much more efficiently. Tiles and shortcuts of pre-installed apps also take up much less space. This latest Windows update also enables users to remove more of the pre-installed applications than before, including 3D Viewer, Calculator, Calendar, Groove Music, Mail, Movies & TV, Paint 3D, Snip & Sketch, Sticky Notes, and Voice Recorder. Under the hood, Microsoft has spun out the Start menu into its own running process. In theory, this will make for a much faster launch time, as well as increasing responsiveness.

6 Separated Cortana and Search Bar

Many users will rejoice to learn that the search bar and Cortana have been separated. You can now enable/disable Cortana as you see fit. Windows update will ask you what you want to do during the install process. If you choose to deactivate Cortana, you can relaunch it at any time by clicking on the dedicated icon. The search bar also tracks your recent activity and local files. This means that if you enter a search term that matches a program installed on your machine, this is displayed alongside any documents you've created. You can now also choose to filter searches specifically by "Apps" as well as documents, email, web and more.

7 Snip & Sketch

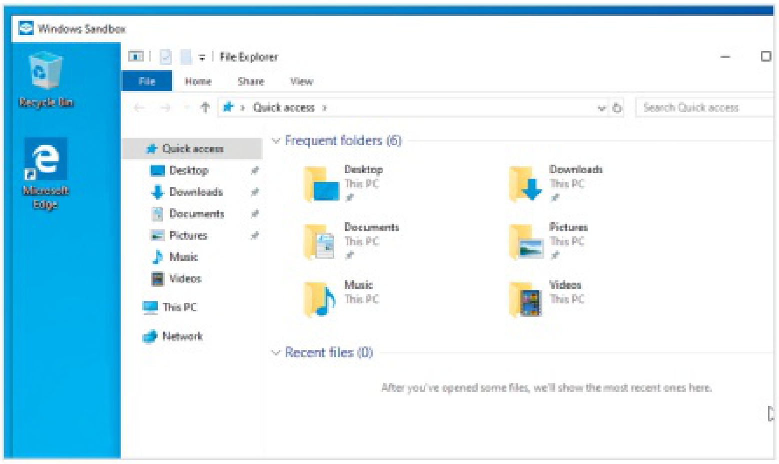
The Snip & Sketch app was introduced in the last update, but Microsoft has made improvements to it for the May 2019 upgrade. The app now has its own settings page. Users can even launch the tool by pressing Print Screen. This can be turned on/off depending on your preference. Previously, Windows 10 only supported screenshotting the main active window; users can now configure the app to just take screenshots of windows, which makes it much easier to screenshot one application. Snips are saved automatically to the clipboard, and then can be pasted to another app, such as Paint. Users can also configure Windows 10 to prompt you to save snips before closing.

8 Super Sticky Notes

In October 2018, Microsoft upgraded the Sticky Notes app to sync notes across all your Microsoft devices, making the app far more useful than before. This functionality has now been extended to include synching any sticky notes you create to the Microsoft OneNote website, enabling you to access them even them from non-Windows devices. Try enabling dark mode with Sticky Notes to sample the new visual effects. ⏻

[HIGHLIGHT]

WINDOWS SANDBOX



After you've opened some files, we'll show the most recent ones here.

Running executable files has always been risky; Microsoft is trying to address security concerns that may arise from installing unverified EXE files. Power users will be used to setting up and installing a virtual machine to test some files before installing them on their PC, but with the new Windows 10 update, Microsoft has come up with a neat solution: Windows Sandbox. It creates a virtual desktop isolated from your actual Win 10 desktop. The feature will be part of Pro and Enterprise Windows 10 editions. It uses hardware-based visualization for kernel isolation. This relies on the Microsoft's hypervisor to run on a separate kernel, which isolates Windows Sandbox from its host.

Each time the app is opened, it creates a lightweight (100MB) version of Windows 10. So, each time it starts, it loads a functional equivalent of a brand new installation of Windows. Users can then install and test new apps, files, and code in this virtual sandbox. Once you've finished testing, you close the app, and the sandbox disappears. Users no longer need to install their own virtual machine.

The app uses an integrated kernel scheduler, smart memory management, and a virtual GPU. It requires Windows 10 Pro or Enterprise Build 18305 or later, AMD64 architecture, virtualization capabilities enabled in BIOS, at least 4GB of RAM, at least 1GB of free disk space (ideally SSD), and at least two CPU cores. To get started, open the Sandbox app from the Start menu or search bar. From there, you can open the Sandbox version of your browser, and download and run your suspect file or program.

© MICROSOFT WINDOWS 10 OS

BUILDER'S HANDBOOK

(00) If you're reading this magazine, you probably know a thing or two about computers, or at least want to learn something. When it comes to building your own PC, there are numerous pitfalls to avoid and tricks to bear in mind. You need the right tools, the right knowledge, and the right level of emotional resilience to keep on trying when something inevitably goes wrong.

Building your own computer won't necessarily be cheaper and will definitely be harder than buying a complete system, but it affords you more control over the capabilities of your hardware. There are numerous issues to contend with when setting out to build a PC, even if you're a seasoned hardware guru, so with that in mind, here's some of our best advice.

noctua
NT-H1
AMD
ADATA
Ultimate
Solid State Drive
SU630
CORSAIR
V-NAND SSD
970 EVO
NVMe M.2
SAMSUNG
1TB

(01)

Plan Your Build

The first thing you should think about is what you actually want your build to do. Is it a beefy 4K gaming machine? A video-editing platform? A plain old work PC? Whatever the reason, it's important to nail down the build's purpose first. This will determine just about every aspect of the finished build, from your choice of processor to what OS you're going to install. Consider where the PC will sit—on your desk at work, or underneath your TV in your living room? If there are any key components you want to include—such as a specific case, or a GPU that is ideal for your chosen purpose—work that out sooner rather than later. Be sure to do a little research on alternatives, though.

(02) Acquire Knowledge

Do your research! There is a wealth of information strewn across the Internet, from tutorials to reviews—and there's plenty of that in the magazine you're reading right now, too. Reviews are an extremely useful source of knowledge when it comes to choosing which parts you're going to use—flip forward a few pages, and you'll find some great ones. Manufacturers' websites are also worth a look; most have PDFs, manuals, and specification lists that can prove invaluable when it comes to actually building and setting up your new rig.

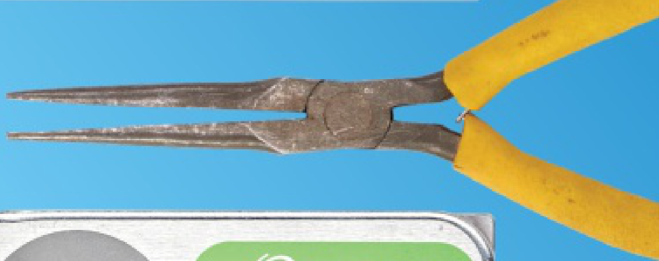
Whether you're new to PC building or a veteran, we can all learn something

By Christian Guyton

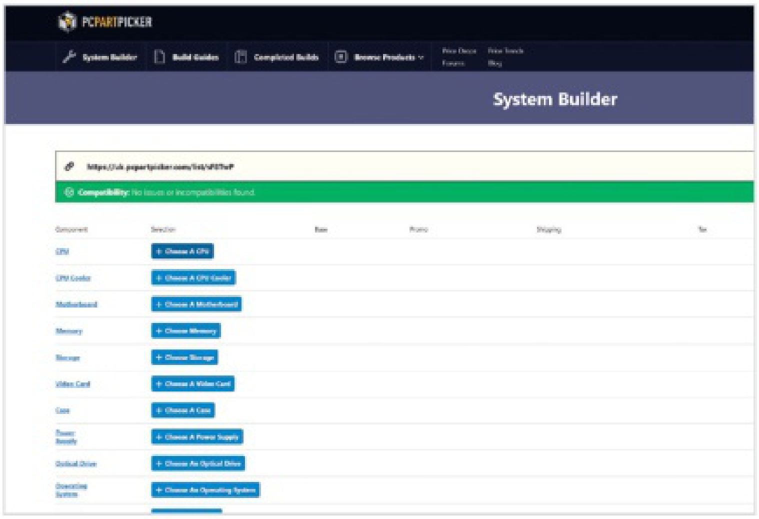
NVIDIA
RTX 2080

AMD Ryzen 5 2600X
AMD RYZEN

GIGABYTE
X470 AORUS GAMING 7 WIFI
AORUS
Socket AM4
DDR4



SEAGATE
IRONWOLF
NAS
12TB
IronWolf
ST12000VN0007
seagate.com
SATA AF



Compatibility: No issues or incompatibilities found.

(03)
Make a Part List

Once you've got some ideas about what you want your finished build to look like, it's time to get organized and list the components you want to use. A trip to http://pcpartpicker.com (pictured above) will do you good here; not only can you easily tally up your budget and keep a running list of components you want to use, but the website flags up any compatibility issues that you might not otherwise notice. Consider your budget carefully at this stage—it's all too easy to drop too much on your GPU and not leave enough for a decent power supply. Unless you're in a major rush, it's usually worth waiting until components are on sale—you should be able to chop off a comfortable 10 or 20 percent from the final price with a little patience. And remember: RGB lighting might look nice, but put performance first.

(04)
Strip It Down

We always recommend starting any build by stripping your case down to the bare essentials: Remove any side panels, dust shields, and windows. If you're not using the hard drive cages or additional brackets, remove them and don't put them back in; this helps to improve airflow by maximizing negative space inside the case, and leaves more room for cable management. Be careful when removing thumbscrews, particularly on glass panels. It's all too easy to leave an unappealing smudged fingerprint on your otherwise unblemished case.

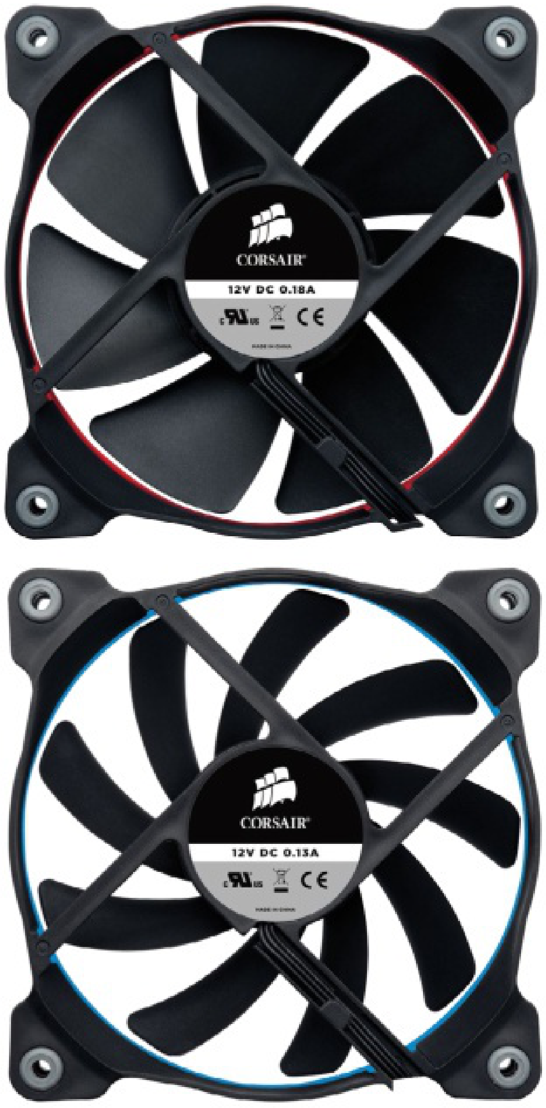
(05)
Part Storage

Don't throw away your boxes. The box your case came in, in particular, is useful both for storing panels during the build process and for holding the boxes of whatever components you're putting inside. If, like us, you're building PCs on a regular basis, this can be very helpful when it comes to keeping track of which component is in which case. In addition to good organization, keeping the boxes comes in handy should you need to make use of a warranty and get a part replaced. Particularly when working with cases that have a lot of glass, storing window panels between the polystyrene that comes in the box can prevent them from being scratched or smashed.

A stripped-down NZXT H400i microATX white mini tower case.

(06)
Choice of Fan

To keep your case cool, choice of fan is vital. In broad terms, fans fall into one of two categories: bulky static pressure fans, and thin many-bladed airflow fans. The former are designed for high-pressure environments, such as moving air through a thick heatsink, while the latter variety moves more air quickly through the case, but with reduced force. Mounting multiple airflow fans inside your case ensures—as their name implies—good airflow, but static pressure fans are vital for radiators if you're using an all-in-one cooler. Some fans utilize magnetic bearings to "levitate" the fan, which provides less noise and longer lifespans, but they typically come at a greater cost.



Same fan, different blades. The thick blades are optimized for high pressure, while the thinner blades maximize airflow.

(07) Fan Management

Most cases come with one or more fans pre-installed. These are typically stock fans from the case manufacturer or one of its partners; when it comes to keeping your build cool, they do the job, but generally don't measure up to fans purchased from dedicated manufacturers. Whether you're looking

A pair of Silent Wings fans is included as part of the package when you buy the Silent Loop 240mm AIO.

© HTTP://PCPARTPICKER.COM

for high-performance cooling or silent running, there are often better options available. If you're upgrading the case fans, do that before building. If there's still room, however, it's worth considering keeping the stock fans inside the case as well. Most stock fans can be installed in the front or back of the case they come in, so if you're replacing your rear fan with something flashier, it's a good option to push the stock fan to the front of the case to pump up the airflow.

(08) Cable Threading

With smaller or cheaper cases, which might not have as much space for tucking away your cables, installing your PSU early and threading through power and I/O cables before installing the motherboard can make your life a lot easier. Using cable ties is the way to go here, unless you've gone for a case that includes integrated cable management options, such as Velcro straps for securing cable bundles. Don't forget that you can feed smaller cables directly underneath the motherboard before installing it. Cheaper PSUs are likely to come with a bundle of cables you won't be using, so neatly pack these together with a cable tie, and store them out of sight—ideally underneath the PSU shroud, if your case has one.

(09) Right Direction

Fan orientation sounds simple, but it can be easy to get wrong. Most fans include small arrows on the plastic frame, indicating which direction the fan spins in, and which direction it pushes air in; alternatively, just check which side of the fan the power cable protrudes from. If you're mounting multiple fans on a single section—such as two fans either side of a heatsink tower, or stacked fans in the front of your case—make sure they're pumping air in the same direction for maximum efficiency.

(10)

Speed Control

Fan speed is an interesting topic; higher RPMs (revolutions per minute) are obviously going to increase airflow, but also produce more noise. Smaller fans demand a higher RPM to work effectively, so don't go

(11)

BUILD IT YOURSELF?

In broad terms, building your own PC will bleed your wallet less than buying a pre-built system, but this isn't always the case. If you're patient, waiting to snap up decent parts on sale, you can always assemble a powerful computer on a sensible budget, but pre-built models do have their advantages: Tidy internals and manufacturer-assured assembly mean that issues such as overheating and component incompatibility are seldom a problem. It can also be a relief to have that manufacturer warranty to fall back on. Some even come with lifetime coverage.

A pre-built system lacks a few things against custom builds: They're not bespoke, and many are needlessly tricky or even impossible to upgrade. If you're looking for the ideal purpose-built PC, you're better off taking the leap and assembling it yourself. Bulk-purchasing components means that pre-built systems can contain high-end parts at a relatively low premium, and there's a certain degree of assurance that the chosen parts will function optimally together. Many come with unique cases that can't be purchased standalone. These are often extremely nice to look at, but a challenge to actually work in should you want to fiddle around with your rig's guts.

Pre-built systems have come far in the past few years. Current offerings from companies such as Digital Storm, Origin PC, and Corsair are powerful and effective, although they will result in a heftier price point. Higher-end pre-builds are generally a better option—if you're assembling a PC on a tight budget, DIY is often the way to go. Ever evolving standards mean that prices are always in flux, and trying to build your own computer from scratch can be a potential minefield of bad prices. There's also the funny middle ground occupied by groups such as Xidax, who will build a custom PC on your behalf—for an additional fee.

Pre-built systems can have some very elegant cases that are otherwise out of reach.

(12) TO RGB OR NOT TO RGB?

RGB lighting is a topic of much debate both at the Maximum PC office and on every single computer hardware forum in existence. There's no denying that filling your build to the brim with LEDs can result in a computer that looks like a cross between a sports car and the most expensive *Star Trek* prop ever, but "expensive" is often the operative word there. It's tempting, too. RGB coolers and fans are becoming more prevalent, so it's easy to be drawn in. Those little additions often add up, though.

A pair of premium maglev case fans from Corsair will run to around 30 dollars, while their RGB counterparts cost easily that much for a single fan. Stick-on LED strips aren't too expensive, but can require expansion kits and RGB controllers that drive up the price. And, of course, you need a case that shows off your multicolored lights—that means tempered glass or even RGB-focused cases, which could result in a less than sensible total cost. At the very least, control software for most branded RGB gear is free to download.

A good rule of thumb when it comes to RGB is to simply ask if you could get the same performance for a cheaper price without the lighting. If you're going to spend an extra 50 dollars on a case just because of its glass front, consider how much time you're going to spend looking at your PC against how much time you're going to spend looking at the screen. Putting that money toward a superior monitor is always going to serve you better, especially if you're operating on a budget. But if you've got the money to burn, or you come across an RGB piece that outperforms one without, go right ahead and turn on the rainbow.

with anything smaller than 120mm for your case unless the circumstances demand it. Some cases come with an integrated fan control unit, which enables you to adjust fan speeds on the fly—just make sure you're not leaving them on the lowest setting when gaming in 4K.

(13) Processor Cooling

Case fans are great, but CPU cooling is crucial in keeping your rig running under stress. There are three options: a traditional air cooler, full liquid cooling, or an all-in-one (AIO) cooler unit that uses both fans and liquid coolant. The first is typically what comes in the box with your processor—these stock coolers are decent enough, and generally not too hard to install, but don't provide high-level cooling. Complete liquid-cooling loops are tricky to install and cost significantly more, though their performance is often unparalleled. AIO coolers are frequently the best option, providing top-notch cooling with a large degree of flexibility, and little to no maintenance. If you're overclocking your CPU, a good AIO cooler is heartily recommended.

LED
USB
POWER
FAN 3
FAN 2
FAN 1
NOTE- "For Adaptive Noise Reduction, please refer to the Fan Connector section in the manual. DO NOT connect PWM-based AIO pumps".
H200i

The fan controller has been developed to analyze the noise in the chassis and adjust the fan curves.

(14) Air Pressure

There are two possible options for maintaining good air pressure inside your build. Balanced air pressure means the case draws in a similar amount of air to how much it pumps out, keeping airflow steady, and temperatures lower. Positive air pressure means your build draws in more air than it pumps out—this can prevent air entering through unfiltered sections of the case, potentially reducing dust build-up. The difference in temperature is relatively minimal, but if you're serious about cooling, balanced air pressure is generally better—test both out using stress-testing benchmarking tools such as Prime95 if you're curious about the results. There is a third option—negative air pressure, the (surprise) opposite of positive pressure—but you want to avoid this, as it tends to result in build-up of dust inside your case.

Keeping your processor cool when under load is essential, and there are several options you can consider.

(15) CPU Installation

The core of what makes your PC tick, central processing units come from two primary manufacturers: AMD and Intel. AMD CPUs are a little easier to install; simply lift the retention arm, slot the CPU into place by lining up the gold triangle on one corner with the matching corner on the socket, then lower the arm back into place. All done! Intel CPUs are a smidge more complex, with the pins mounted on the motherboard rather than the processor chip, and a metal bracket that sits over the CPU socket. Lift the retention arm, then slide the bracket out from under the fixed Torx screw, and raise it to reveal the socket. Line up the CPU and place it in the socket, then lower the bracket and retention arm back into place. Intel motherboards come with a plastic cover over the CPU socket; this comes off automatically once the CPU is in locked in.

Grab Your Gear Clothes may make the man, but tools make the PC builder. Here are some of the most helpful items you'll come across.

(16) SCREW BOWL You can splurge on a magnetic bowl for your screws if you want, but really, any little bowl will do the trick. Even a simple kitchen ramekin will work. The important thing is keeping all of your screws in the same place when you're working on a rig; they can be easy to lose, and that only leads to frustration.

(19) ISOPROPYL ALCOHOL If you're planning on switching out your processor or cooler, you're going to need this stuff. It's inexpensive, and nothing is more effective when it comes to cleaning off dried thermal paste or dirty smudges on metal. As an added bonus, it's one of the few substances that isn't going to kill your components if it gets on them. Keep it away from your eyes, though.

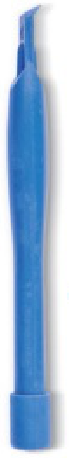
IPA Isopropyl Alcohol
Isopropanol 99.9% Pure

(17) THERMAL PASTE Most coolers come with paste, but our go-to is Noctua's NT-H1. It's not very expensive, and Noctua coolers come with some—one tube is good for multiple applications, and it's a pleasingly thick, non-conductive paste that does a good job of transferring heat. You only need a pea-sized dot on normal CPUs.

(18) CABLE TIES These are the most important thing for any PC builder. They're dirt cheap online, and come in a variety of sizes for different uses, primarily for organizing the internals of your rig. Most cases have slots on the frame to strap down cables, and they can be used for tying up loose wires to keep your case tidy.

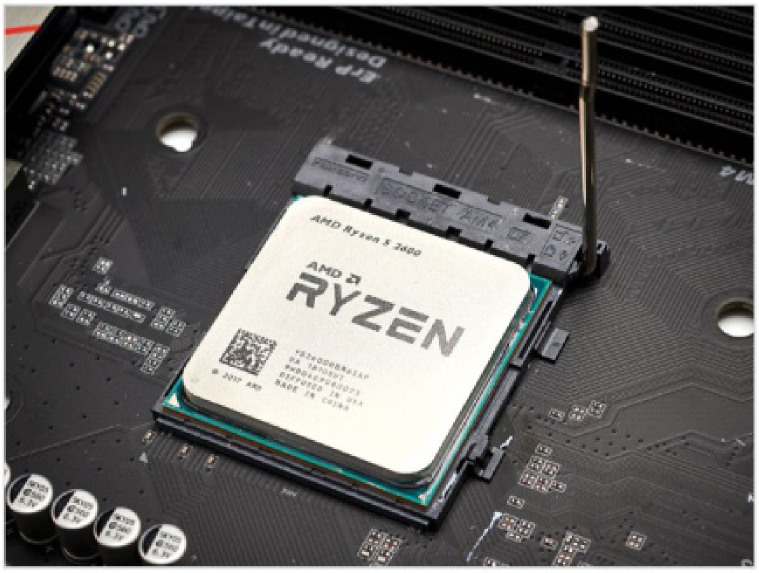
2.0x50mm
3x75mm

(20) SCREWDRIVERS A Phillips screwdriver will serve you well in most situations, but a proper set is worth the money. Allen screws, tiny M.2 drive screws, and bizarre proprietary screws all prove frustrating eventually, unless you've got the right tool to coerce them loose. If you've got a bit more cash, mag-tip screwdrivers can be a godsend when dealing with smaller screws inside a case.

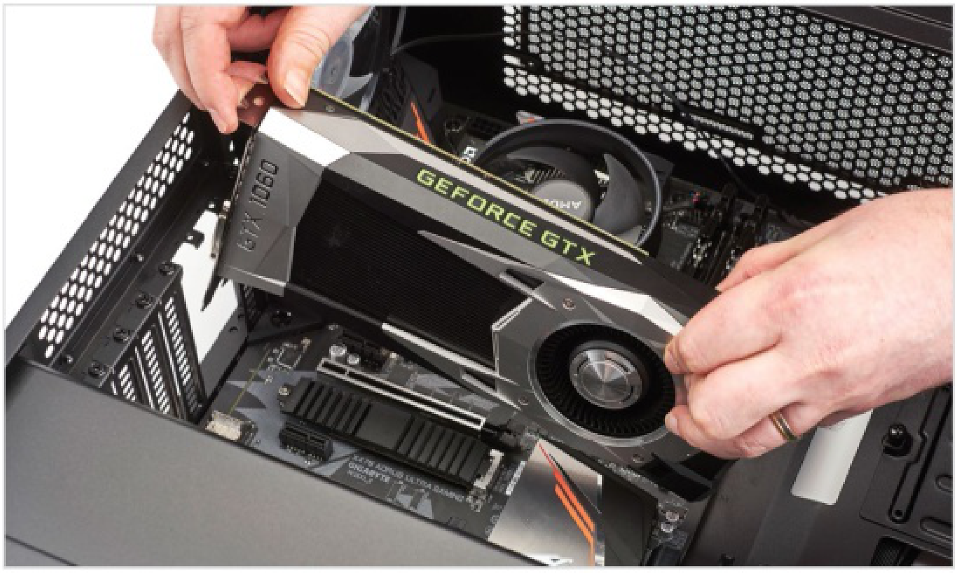


(21) SPUDGER This funky little gadget will set you back barely a dollar or two, and can come in very handy. Used by the tech-dismantling pros at iFixit for prying apart stubborn components, its thin plastic edge can also be used to gently realign bent pins on AMD processors.

© CORSAIR.COM



AMD CPUs are easy to install: Just lift the retention arm, and slot the CPU into place, lining up the gold triangle.



When installing your GPU, remove the two PCIe blanking plates on the motherboard, before dropping the card into its slot.

(22) Memory Installation

RAM is one of the easiest things to install. Memory slots have either one or two clasps on their short edges, so ensure these are open first. Find the notch on the base of the memory stick, and line it up with the notch in the memory slot, then push it down. It should click into place—the clasps pop shut automatically. Bear in mind that memory slots are usually not in numbered order on the board; they are typically color-coded to indicate which slots use which channels. For dual or quad-channel support to work properly, the RAM needs to be installed in the correct slots. If you're unsure, check the motherboard's manual—it'll let you know exactly which slots to use.

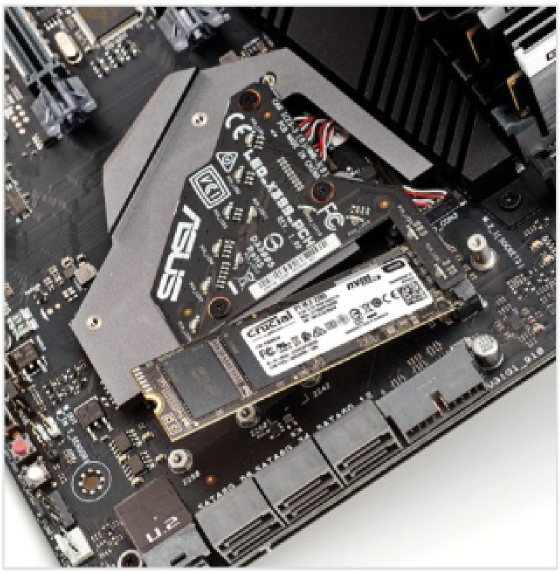
(23) M.2 Installation

If you're using conventional HDDs or 2.5-inch SATA drives for storage, you need to install them in the case, then run a cable from them to the motherboard. The flashier M.2 SSD format is installed directly on the mobo. Make sure the mounting peg is in the right position for the length of your SSD, then remove the tiny Phillips screw, and fit the M.2 into the drive slot. Apply a little pressure to hold it down, and replace the tiny screw. Many motherboards come equipped with a heatsink for the M.2 drive—this needs to be removed before installation, then returned to the board once the SSD is in place. Don't forget to remove the plastic covering the thermal pad, or you're likely to smell burning once your build is up and running.

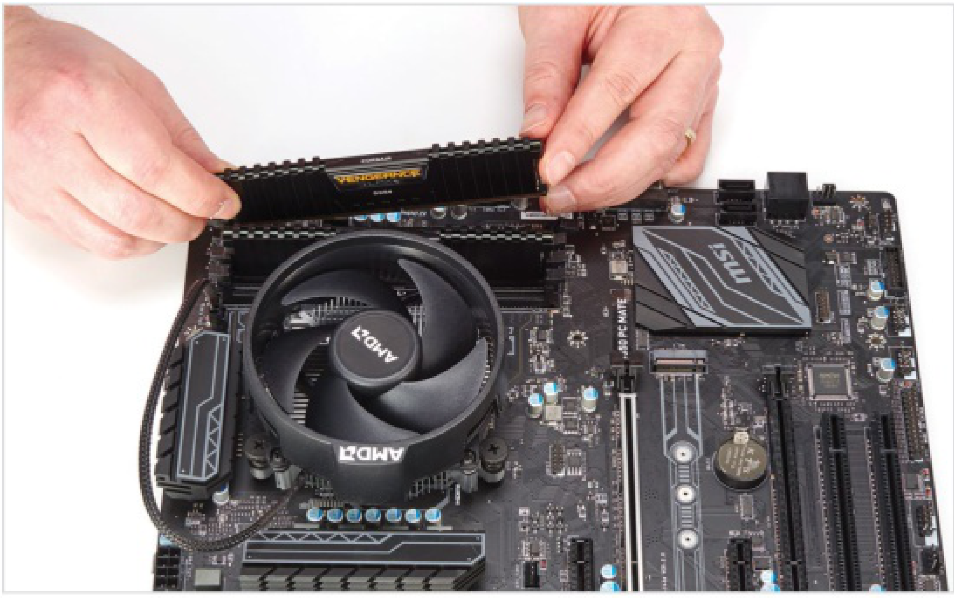
(24) GPU Installation

The graphics card is often the bulkiest piece of gear going on to your motherboard, so take care when installing it. These cards can be heavy, and dropping one on to a board risks damaging both components. Remove the expansion slot covers from your case first, then ensure that the clip on the PCIe slot is released. Like the clasps on RAM slots, it snaps closed once the component is properly installed. Position the GPU with the rear I/O in line with the rear of the case, then gently push it down until you hear the clip. Secure it to the case with screws straight away. This principle can also be applied to other parts that are installed in the PCIe slots, such as soundcards and other expansion pieces. Be sure to use the uppermost slot for your GPU to ensure the best performance.

M.2 SSDs are installed on the mobo: Undo the little screw, and slot the drive into position.



RAM installation isn't much more complicated than pushing it into place.



(25)

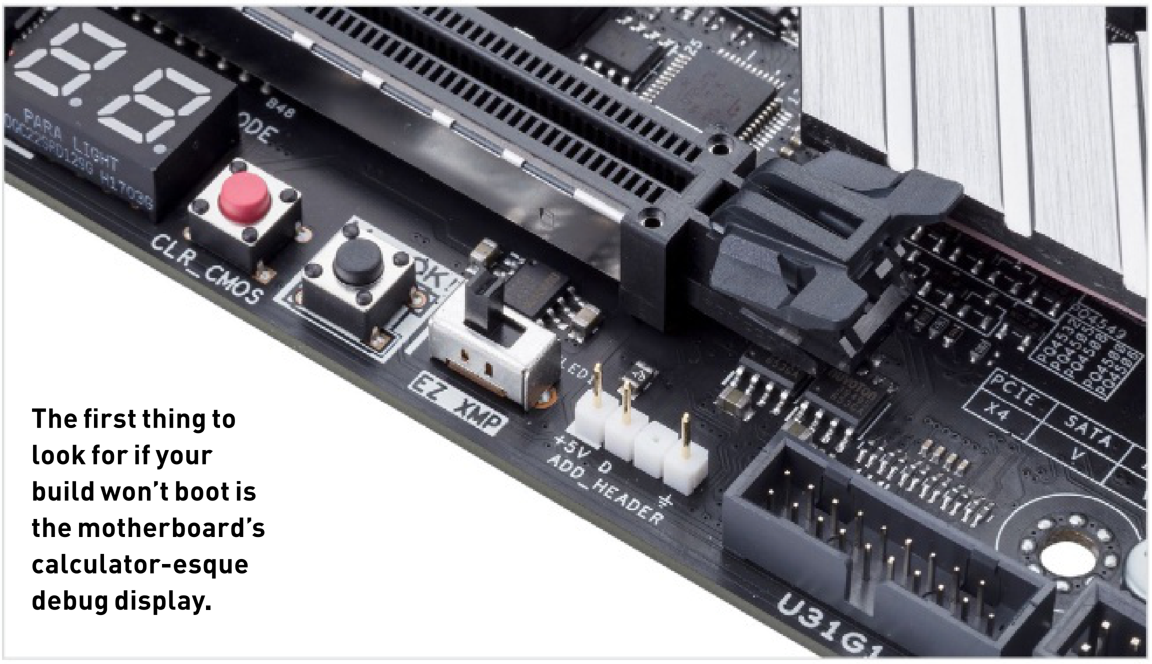
Foggy Memory

When a build won't boot, memory is frequently the issue. If you can access the BIOS, you should be able to see whether the memory is detected properly. If not, or if it isn't seeing all of it, try removing and reinstalling the RAM. Check that the sticks are installed in the correct slots; if they are, but it's still not running, give the additional slots a try. As a last resort, try reseating your graphics card and CPU.

(26)

Power On

The first thing to look for if your build won't boot is the motherboard's debug


The first thing to look for if your build won't boot is the motherboard's calculator-esque debug display.

display. Not all mobos have one—it's usually a calculator-esque seven-segment display, although some high-end boards have a small screen for displaying error codes. Take to Google or consult the motherboard manual, and you should be able to isolate the issue. If you're not sure, or your board doesn't have a display, try these next few tips.

(27)
Energy Checks

Is everything plugged in? It sounds silly, but we've all done it. The GPU isn't connected to the PSU, the front I/O wires aren't powered, the boot drive isn't plugged in properly. If everything looks like it's in the right place, but you're still staring at a black screen, try using a different cable for your display; HDMI and DisplayPort cables are notorious for failing when you need them most, particularly if you're using cheaper ones.

(28) OS Install

Sometimes, it's Windows that's causing the problem. This is particularly likely to occur when transferring an older drive to a new build, generally caused by driver or program conflicts, resulting in a failure to boot. OS files are susceptible to corruption, too. If this is the case, resets and updates aren't likely to help; the only option that might fix the problem is to reinstall Windows completely to your boot drive. We usually recommend installing a fresh copy of your OS with each new build.

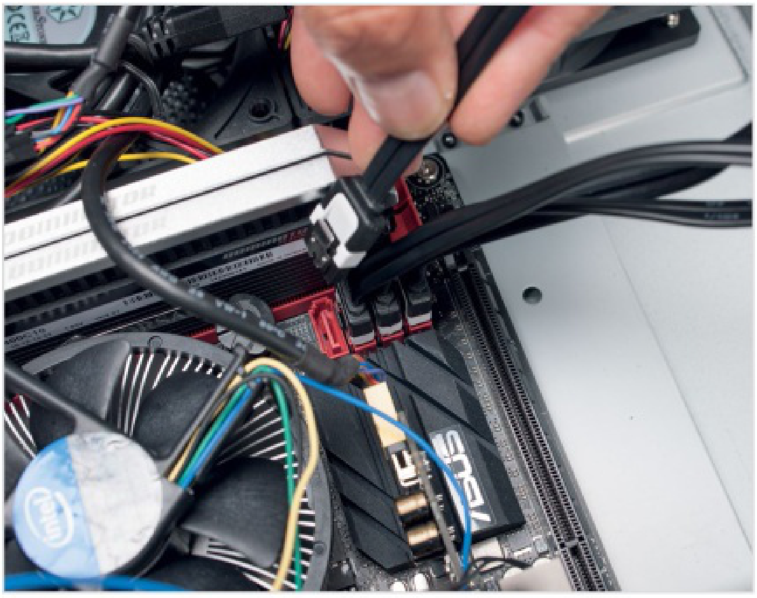
(29) Hardware Testing

Hopefully it won't come to this, but sometimes components simply die. If you want to do some final checks before calling the RMA line, you generally need a second (functioning) PC. You can test RAM sticks by plugging in each one separately and attempting to boot. For other components, you need to swap each one out and test it on another motherboard, or replace it with another part you're certain is functioning.

(30)
BIOS Update

Most modern motherboards support updating the BIOS via the Internet, but if yours doesn't, you can usually grab the update file from the manufacturer's site. Download it on to a blank USB drive and plug it into the mobo, then find the update option within the BIOS's advanced mode. Select "Update from storage," locate the file on the memory stick, and you're all set.

PC not booting? Check everything is plugged in.



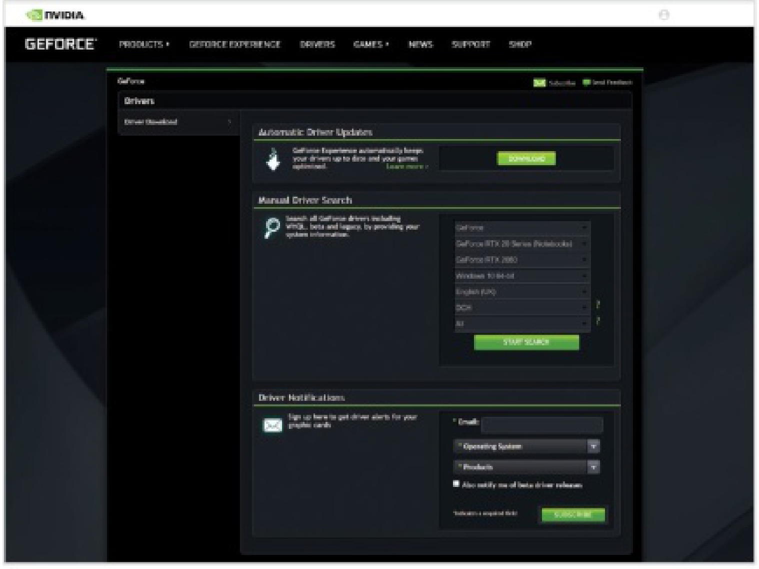
(31)
STAY FROSTY

Fully customized liquid cooling can be a monster to do right, but it does come with some major advantages. Lower running temperatures are a given, generating more potential for overclocking, but the key draw for many users is the significant reduction in sound. Fans can be run slower, resulting in less noise. Creating your own liquid-cooling loop is a costly process, though, demanding a budget of at least $500 to do properly.

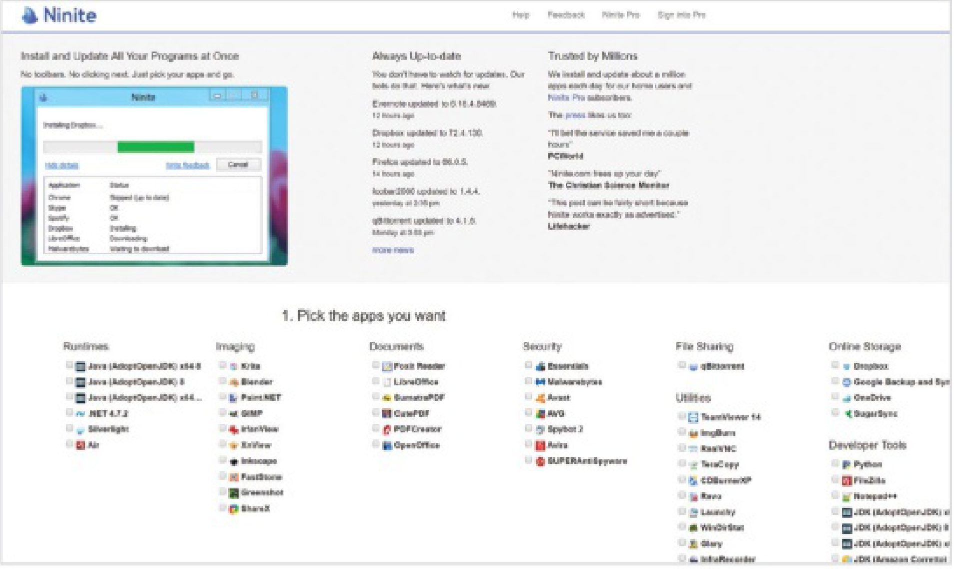
Planning out the build is absolutely necessary if you're going to be installing coolant tubes in your case. Take a side-on photograph of your case, and use your picture-editing software of choice to plan out the positioning of your components and tubes, making sure to ascertain which direction you want the coolant to flow. The larger your case, the easier it becomes; reservoirs and radiators can take up a lot of space. Smaller cases may demand the drilling of holes through metal frames to feed through tubing. Angled fittings can remove the need for bending your tubes; while flexible tubing is an option, hard tubing is easier to secure in place, and tends to look better, too.

The pump needs to be gravity-fed by a reservoir, so vertical installation within your case is required. When it comes to radiators, it's worth having at least 120mm of radiator space allocated per component being cooled. For example, if you want to cool your CPU and your GPU on the same loop, you're going to want a minimum radiator size of 120 x 240mm.

Filling your custom loop with coolant can be a nerve-wracking ordeal.



If you want your graphics card to run as well as it possibly can, make sure you're using the latest drivers.



Once you've built your new rig, you'll want some software to run on it; the Ninite website is a good place to source your essential apps.

(32) Installing the OS

The best way to go about installing a new OS is to grab a copy of Windows from http://bit.ly/Win10MediaKit, if you've still got your digital key (or you have a Windows 10 license connected to your Microsoft account). Download the Media Creation Tool and Create Installation Media on to a USB drive, then simply plug that stick into your new build, and boot it up. If it doesn't work, head into the BIOS and adjust the boot order, so that the system boots from the USB first. From there, just follow the on-screen prompts to set up the operating system.

(33) Update Drivers

To get your graphics up to speed, head to either the Nvidia or AMD website (depending on your GPU), and download the most recent driver update. If you're using an older motherboard, you'll want to update the chipset first. Just find the product on the manufacturer's website, and grab the latest drivers. You'll also want some additional drivers here; look for audio and LAN drivers in particular, and remember that the chipset needs to be installed first.

(34) Light Show

Custom lighting can be a tricky business. It's easy to buy an assortment of compatible RGB components and click a lighting preset in the manufacturer's own RGB control software, but if you want to go truly flashy, you're going to be installing light strips. These aren't too expensive, but you also need adapters and potentially an RGB controller, too.

When it comes to installing them, ensure that the strips themselves aren't visible from the windowed side of your case; light should always be shining on your components, rather than out of your case. Find spaces and corners to conceal them, either under the lip of the case's edges or beneath the black border of a tempered glass panel. Using two strips installed at right angles in a corner creates a more even spread of light across your motherboard, but if you're using fully addressable RGB lighting, it's important to ensure that they are synchronized up properly.

(35) Installing Software

Presumably, you're going to want to put some programs on your shiny new computer. A good one-stop-shop for this is http://ninite.com, which enables you to choose from a selection of key programs to quickly and easily download to your C drive. Ninite also keeps these up to date automatically, if you want it to. If you're a gamer, you'll likely have to do some busywork; while Steam is on Ninite's list, other platforms, such as Origin and the Epic launcher, are not. Similarly, if you use higher-end image or video manipulation software, you're going to have to seek it out yourself.

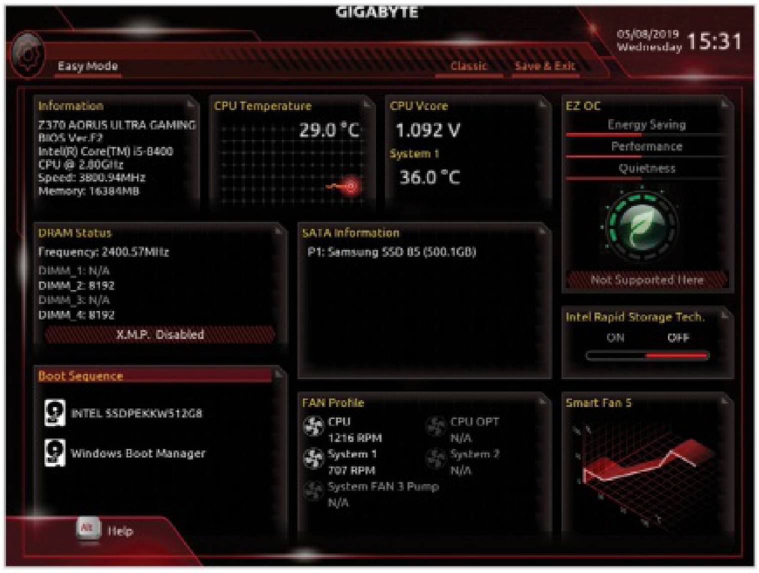
***Maximum PC's* RGB light show Dream Machine 2019.**

(36) Tweak RAM Settings

You're also going to want to take a look at your RAM settings. Double-check that the memory is running at the correct frequency and CAS timings, then enable XMP settings if you're overclocking. You can attempt to manually pump this up, too, but be careful—DRAM voltage increases of more than 10 percent can prove lethal to your sticks.

(37) Color Coding

Unless you're going for a very specific color scheme, it's generally best to stick to white lighting. This gives your components a good amount of definition, without drowning out any RGB effects your mobo is putting out. Bright single-color LED strips are likely to just highlight the predominant colors on your components, flooding your build's appearance with blue or red. If your strip allows for brightness adjustment, opting for a slightly more conservative light level is



05/08/2019 Wednesday 15:31

Information
Z370 AORUS ULTRA GAMING
BIOS Ver.F2
Intel(R) Core(TM) i5-8400
CPU @ 2.80GHz
Speed: 3800.94MHz
Memory: 16384MB

CPU Temperature
29.0 °C

CPU Vcore
1.092 V
System 1
36.0 °C

DRAM Status
Frequency: 2400.57MHz
DIMM_1: N/A
DIMM_2: 8192
DIMM_3: N/A
DIMM_4: 8192
X.M.P. Disabled

SATA Information
P1: Samsung SSD 85 (500.1GB)

Boot Sequence
INTEL SSDPEKKW512G8
Windows Boot Manager

FAN Profile
CPU 1216 RPM
CPU OPT N/A
System 1 707 RPM
System 2 N/A
System FAN 3 Pump N/A

Getting to know your motherboard's BIOS is crucial if you want to get the very best from your new rig.

a good call. Addressable RGB is great, provided you ensure that you can synchronize to retain an appealing pattern across your entire build.

(38) Search Warranty

If you can't work out what's wrong with your build—or if you can, but you can't fix it—there's one more port of call: the warranty. Most brands come with a decent warranty, and some components even come with a lifetime guarantee. Customer service is generally good—if they can't diagnose the issue, you're likely to get a fresh replacement part, provided you haven't done something horribly wrong to the offending component. Don't be afraid to raise a ticket even for minor issues; when it comes down to it, they are the experts.

In addition to general design quality and longevity, this is one of the key reasons we recommend sticking to recognizable brand-name components. If you're not sure when purchasing, check the manufacturer's website, and read some reviews on reseller sites. If you can't find many (or any) reviews, tread carefully; don't be lured in by a low price and an obscure manufacturer name.

(39) BIOS Mastery

Knowing how to modify your build's settings in the BIOS is a vital part of proper PC building, enabling you to get the absolute best out of your hardware. We deal with CPU overclocking on the right, but that's not all the BIOS can do. Fan curves are a great place to start; set a low curve (between 35 and 50 percent power) for any temperatures below 60 C, then ramp them up. This guarantees a quieter experience when your PC is idling.

(40) Speed Up Booting

There's a number of ways to speed up actual use of your PC. Fast boot or boot order settings can be useful to tweak, and ACPI settings enable you to adjust system-level power states and how they interact with input from peripherals. If you've got an Intel board, consider turning on the Rapid Start function, which speeds up resume times from PC hibernation. Remember that your operating system boots faster from an M.2 drive than a SATA one.

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(41)
STOP THE CLOCKS

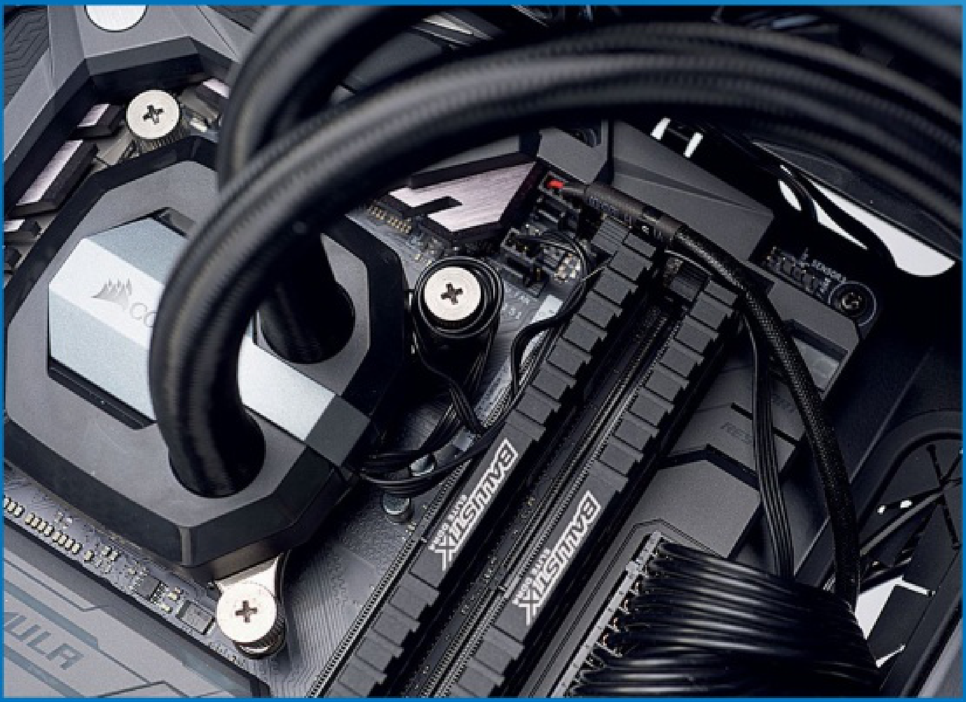
Overclocking is a complicated business. If you're dead-set on pushing your hardware to the absolute limits, it's best to track down some serious in-depth guides on how to do so without bricking your build. Hardcore overclocking kicks the crap out of your processor and motherboard, which can result in some disastrously high temperatures if you're not careful.

At a fundamental level, overclocking is achieved by raising the frequency at which the processor runs, and increasing the voltage supplied to the components to compensate for the additional power. Different motherboards and CPUs have differing limits when it comes to the overclocks you can achieve; this is done by accessing the motherboard BIOS and manually raising the frequency at which the CPU attempts to run. Depending on the capability of the processor, this could be anything from 0.1GHz to 1GHz more. If you're running a high-end chip, you should be able to squeeze at least 0.5GHz out of it.

Keep raising the operating frequency in the BIOS. At a certain point, the CPU will refuse to boot. To get past this, head back into the BIOS and raise the voltage, usually by 0.05V at a time. Of course, doing this raises the temperature in turn. It's vital to have decent CPU cooling if you're going to overclock; a bundled stock heatsink and fan isn't going to cut it, so be sure to splash out on an upgrade.

If you've got a high-end AIO cooler, though, you can use a stress-testing program such as Prime95 to push your CPU to the limit, and assess the maximum running temps you're likely to hit. Test it between changes to the BIOS settings to ensure that you're not in danger of killing your processor—in theory, though, modern chips should shut off automatically when they reach dangerous heat levels.

After a while, you'll hit a stage where it's impossible to get the frequency any higher, regardless of the applied voltage. At this point, dial it back by 0.1GHz (this constitutes a more stable overclock), and run some more benchmarks to ensure it isn't about to die on you. If your PC crashes or you hit temperatures that exceed safe operating levels, lower the frequency by another 0.1GHz, and try, try again. ⏻



Powerful AIO coolers are a good call for heavily overclocked processors.

VOICE-CONTROLLED SMART HOME

If you utter "Siri," "Alexa," or "OK Google" in **Jonni Bidwell's** home, all the lights go off and the router disconnects

YEP, WE'RE PRETTY CYNICAL ABOUT voice assistants. Other magazines rant and rave about the latest Alexa additions and how they make ordering tat from Amazon even easier. They forgive the chaos that ensues when Siri's name is spoken on TV, as all the iPhones within earshot frantically start offering help.

Tech pundits wax lyrical on the importance of shoving a network stack deep into every appliance in your house so that it can be "smart," and the "smart" appliances can chatter among themselves about their dumb masters. Chances are you've got smart meters installed to keep track of your power use.

The utility companies tell you that smart meters will help monitor your usage, save money, and not be subject to wildly varying usage estimates. That may be true in individual cases, though we bet a lot of people find their utility bills increasing post-smart meter. But mostly, it's because the companies can generate more profit by not having to pay people to drive around reading meters. Instead they'll have to pay people to drive around fixing them on a regular basis.

Be that as it may, voice assistants and network gadgets are here to stay, and as the old saying goes, if you can't beat 'em, make an open-source equivalent and have said equivalent control your home. So, here's our guide to the FOSS-powered smart home, featuring the Mycroft voice assistant, openHAB, Home Assistant, and more. Let's get to it...

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INTRODUCING MYCROFT

There's a Pi-powered home helper on the scene—actually, there are two, and you can use their code

THE MYCROFT MARK 1 LAUNCHED IN 2016, and was powered by a Pi 2, but things have moved on, and it now ships with a Pi 3 at its heart. It's a stylish device, and with its friendly ET-style face, you could almost forgive it for listening in to all your living room conversations. Actually, non-creepiness is part of Mycroft's design—any feature you find invasive or unnecessary can be disabled, thanks to its open-source nature. Mozilla's Privacy Not Included site has a favorable write-up at http://bit.ly/lxf249mycroft.

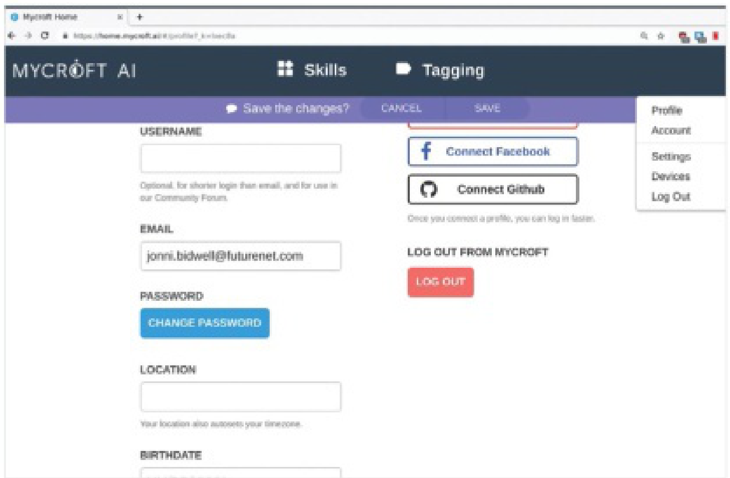
The Mark 1 device is still available for $180, but it was always designed with hackers and hobbyists in mind. A successor is on the way, and the Mark 2 will be much more consumer-friendly (but sadly no longer looks like ET), featuring a six-microphone array, touchscreen, and stereo speakers.

Don't worry, though, hackers will still be able to have their wicked way with it. Mycroft is currently taking pre-orders for the Mark 2, so if you're tempted, check it out at https://mycroft.ai. Alternatively, you can run Picroft, the same software that runs on the Mark 1, on your own Raspberry Pi or Linux box. But first, some Mycroft etymology and terminology.

You probably know that Sherlock Holmes had an older brother called Mycroft. You may even be aware that in Heinlein's classic *The Moon Is a Harsh Mistress,* the HOLMES FOUR computer that accidentally became self-aware was named Mycroft, shortened to Mike. In case you weren't, that's where the Mycroft Home Assistant gets its name. Don't worry, though—despite our best efforts, we couldn't get the device to become sentient, and at no point did we feel threatened by Mycroft. But maybe that's what it wanted us to think....

Scene-setting aside, you'll want to get familiar with the Mycroft nomenclature before you start ensmartening your home, because some of it can be a little confusing at first.

- **Enclosure:** Any device running Mycroft—this could be the Mark 1, a Pi, or your Linux box.



EMAIL
jonni.bidwell@futurenet.com

Set your physical location to ensure Mycroft knows where it is and answers accordingly.

- **Wake word:** The word that pricks up Mycroft's virtual ears. It tries to help you with anything you say after this word.
- **Utterance:** A command or question directed at Mycroft.
- **Intent:** A task the user intends to accomplish; different utterances may have the same intent. Mycroft uses a lightweight intent parser called Adapt. A more complex, neural-network-based parser, Padatious, is also available.
- **Skill:** A function that Mycroft performs in response to an utterance; this could be to relay some information, adjust the temperature on your smart thermostat, or activate your home's self-destruct mechanism. The intent parser decides which skill should be used for a given query.
- **Fallback skill:** If the intent parser is unable to match a skill to a given utterance, a general fallback skill is used. Fallback skills for DuckDuckGo and the Wolfram Alpha knowledge engine are included, which can answer most general queries.

Mycroft has recently begun work on the CommonIoT framework. We make reference to a few different frameworks in this feature, so you may be wondering, why another one? Fair point. It's precisely because there are now so many partially interoperating ecosystems that bridging layers are sometimes necessary.

The important thing is that CommonIoT is available as a Mycroft skill, which enables different platforms to be controlled consistently, and saves skill writers having to fight with natural-language coding.

The prototype Mycroft Mark 2 home assistant retains some of its predecessor's charm, but looks a little more like its proprietary peers.

HARDWARE REQUIREMENTS

Voice recognition is reasonably taxing CPU-wise, so you need at least a Pi 2 to run Picroft. Even that will struggle, and the official word (see https://mycroft.ai/documentation/picroft) is to use a Pi 3. That way, you also won't have to worry about getting Wi-Fi working. Since the Pi's onboard audio doesn't have any kind of analog input, you need a USB microphone. We hit up our friends at ModMyPi and got the reasonably fancy Seeed ReSpeaker mic array, which has four microphones, so can determine the direction of an audio source.

You also need some kind of speaker; this could connect either to the 3.5mm analog output or via USB, or via HDMI if your display has speakers. Bluetooth audio may work, but users have reported problems with this, so it's probably best avoided. You also need at least an 8GB SD card.

Mycroft can run quite happily on a desktop Linux box, too, so long as it has speakers, a microphone, and a reasonably powerful CPU. In fact, it even runs on Android if you're feeling adventurous.

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HOW TO INSTALL PICROFT OR MYCROFT

Let amusing human-computer voice interactions begin!

THE PROCESS OF installing Picroft starts the same way as installing Raspbian: writing an SD card image. There are stable and unstable versions available at https://github.com/MycroftAI/enclosure-picroft. We'll work with the stable image for this tutorial, but do give the unstable one a shot later to see some new features (and possibly bugs). Download the image to your machine—any machine running any OS; just be aware it's 2.2GB zipped and 4.9GB unzipped, so make sure you have enough space. The image can be burned with a graphical program, such as the multi-platform Etcher (https://etcher.io), or the old-fashioned way with `dd` on Linux:

```
$ sudo dd if=raspbian-stretch_Picroft_2018-09-12.
img of=/dev/sdX status=progress bs=4K
```

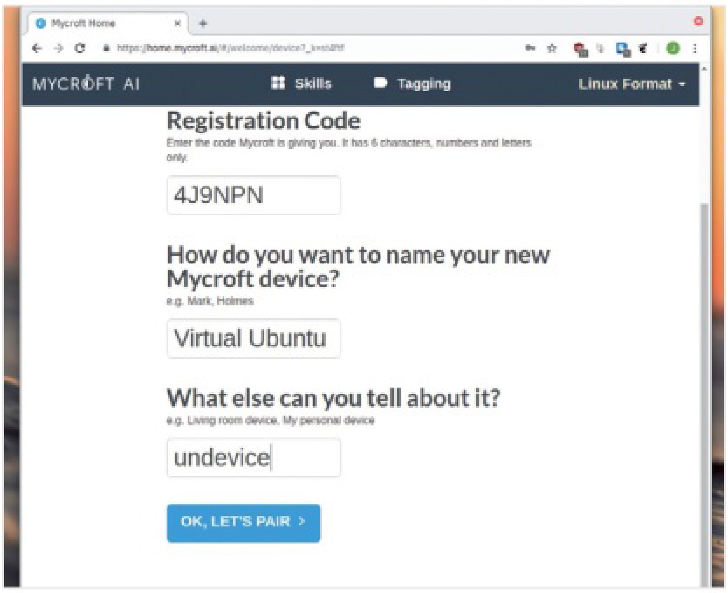
Replace `/dev/sdX` with the appropriate device (the `lsblk` command will help you figure this out if you're not sure). That will take some time to write, so now is a great opportunity to make your first cup of coffee.

When done, put the SD card into the Pi, and fire it up. You need a display and keyboard connected to the Pi to run the initial setup, but afterward, these aren't needed unless something goes wrong. On first boot, Picroft resizes its partition to use all available space on the SD card. When it finishes booting a second time, it asks if you would like some help setting up your system. Unfortunately, this help doesn't include setting up wireless networking, so you need to say no here, unless you're using a wired connection for your Pi.

If no network connection is found, you're directed to a different script, which tries to sort this out. For basic Wi-Fi (WPA or WPA2 with a password), choose the first option, and enter your network's SSID and password. For more complicated setups, use option 3 to edit the "/etc/wpa_supplicant/wpa_supplicant.conf" file.

The Mycroft CLI should start, and you should be able to pair your Pi to Mycroft Home, which we'll get to in a minute. First, though, you need to set up your microphone and speakers via the setup wizard. Exit the CLI by typing `:quit` then restart the setup wizard with:

```
$ mycroft-setup-wizard
```



Registration Code
Enter the code Mycroft is giving you. It has 6 characters, numbers and letters only.
4J9NPN

How do you want to name your new Mycroft device?
e.g. Mark, Holmes
Virtual Ubuntu

What else can you tell about it?
e.g. Living room device, My personal device
undevice

This is the screen you'll want to type your registration code into. We're pretty sure this one will have expired by press day.

First, choose the sound output that best matches your hardware: Analog, HDMI, or USB. Next, set the desired audio level. If you've just plugged in a USB speaker and aren't getting any output, you may need to reboot (by pressing R) for it to be picked up. Then comes the microphone test; only a couple of USB mics and the Google AIY kit are supported out of the box, but other hardware (such as the Seeed ReSpeaker we used) can be made compliant once the relevant drivers are installed. Use option 4 to postpone setting this up if your hardware needs further convincing.

Next you're asked whether to auto-update the master branch, which is a good thing to say yes to. You're then asked if you want to allow passwordless sudo—the default behavior, which is insecure depending on who has access to your Pi. Finally, you have the option to change the default "mycroft" password for the pi user, which you probably should do. Setup then continues the same as on desktop, so skip to the "Creating a Mycroft Account" section.

MYCROFT ON YOUR DESKTOP

For desktop Linux boxes, Mycroft provides a setup script on GitHub that works on Debian, Ubuntu, Fedora, and Arch. It can be made to work on other distros, but some manual setup is required—the script tells you which libraries are missing, and your job is to find the packages containing those. Whatever distro you're running, you need Git to fetch the script. Grab it with:

```
$ cd ~
$ git clone https://github.com/MycroftAI/mycroft-
core.git
$ cd mycroft-core/
```

Then have a look at the "dev_setup.sh" script, because it's imprudent to run random things from the Internet that are going to ask for root privileges, even if the folks at Mycroft are a trustworthy bunch. You'll see that the script sets up a virtual environment so as not to interfere with your Python installation. Once you're happy the script is kosher, run it with:

```
$ ./dev_setup.sh
```

You're now asked which branch you want to check out. The default master branch is considered more stable, so go with this one first. Later, if you're feeling adventurous, you can try the development branch. Next, you should allow the script to automatically update the repo, unless you have some reason not to. The next question asks whether you want to build the Mimic TTS (text-to-speech) engine locally. This takes a long time on an older machine, but is worth it if you want Mycroft to talk to you during those dark times of Internet outage. Finally, you are asked whether to add the Mycroft Helper command path to your profile; this

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makes your life easier, so say yes here. All Mycroft commands begin with `mycroft`, so typing this then pressing Tab helps you manipulate it. You are asked for a sudo password, and then a quite considerable number of packages are downloaded and installed. You might see a warning about an outdated version of Pip (we noticed it on Ubuntu 18.04.2), but this is apparently safe to ignore.

Now we're ready to run Mycroft for the first time, which is done from the "mycroft-core/" directory with:

```
$ ./start-mycroft.sh debug
```

The `debug` option starts a command-line interface and shows extensive startup logs. Once everything's loaded, it gives you a unique six-character registration code to pair this device with the Mycroft Home service. Make a note of that, because we'll need it in a moment. There's not a lot that Mycroft can do until this pairing is complete.

CREATING A MYCROFT ACCOUNT

Visit https://home.mycroft.ai—because the vocal prompts should tell you whether your speakers are working—to create an account from where your Mycroft devices can be managed. Enter the pairing code, and give your device a name and description. The CLI started earlier should acknowledge the new device, and you can enter natural-language questions, commands (started with `:`—type `:help` to see a list), or speak directly to Mycroft through your microphone, audio setup permitting. It tries to answer anything that you precede with "Hey Mycroft."

At this point, you can continue with keyboard and monitor plugged in, which is probably a good idea for the moment. However, if you're planning on a headless Mycroft Pi setup, you're going to be connecting to it over SSH, so you may as well practice that now. You need your Pi's IP address, which you can either ask it for directly, or type the following into the CLI—Mycroft doesn't care about apostrophes, incidentally:

```
whats my ip address
```

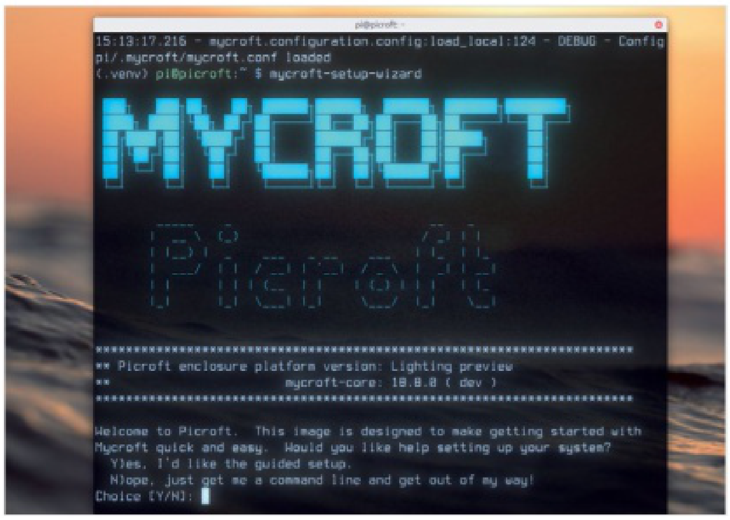
Mycroft should respond vocally, and output something like:

```
>> My network I.P. address is 192 dot 168 dot 0 dot 23
```

This means you can SSH into it from another machine with the following:

```
$ ssh username@192.168.0.23
```

If you're talking to Picroft, the username is `pi` and the password is longer `mycroft` because, of course, you diligently carried out our earlier instruction to change it as soon as possible.



```
15:13:17.216 - mycroft.configuration.config:load_local:124 - DEBUG - Config
pi/.mycroft/mycroft.conf loaded
(.venv) pi@picroft:~ $ mycroft-setup-wizard

******************************************************************************
** Picroft enclosure platform version: Lighting preview
**                          mycroft-core: 18.8.0 ( dev )
******************************************************************************

Welcome to Picroft.  This image is designed to make getting started with
Mycroft quick and easy.  Would you like help setting up your system?
  Y)es, I'd like the guided setup.
  N)ope, just get me a command line and get out of my way!
Choice [Y/N]: 
```

Mycroft's glorious ASCII splash screen. Yet another opportunity for Cool Retro Term to make an appearance.

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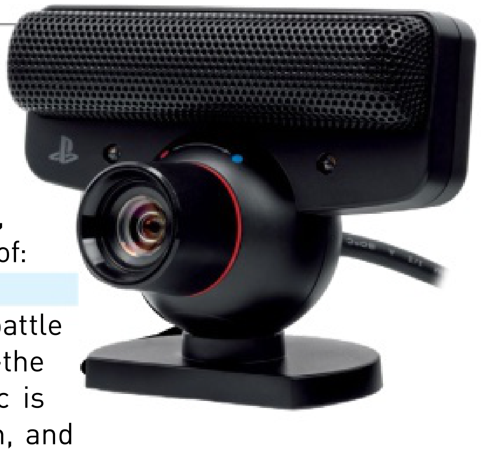
If the mic level in the CLI doesn't respond, quit the CLI with Ctrl-C and check the output of:

```
$ arecord -L
```

If your mic is not detected, you need to battle with sorting out your particular hardware—the fairly ancient PlayStation 3 Eye camera/mic is strongly recommended by the Mycroft team, and works out of the box. If, on the other hand, it is detected there, you may need to install and tweak Pulseaudio.

This is almost exclusively going to be a Pi issue, as all major distros have this already. It was necessary on our ReSpeaker HAT, so check the box below for guidance. You can always return to the CLI client with:

```
$ mycroft-cli-client
```



The PS3 Eye works out of the box with Mycroft, even if we are only using its PS3 ear.

SETTING UP THE RESPEAKER

The Seeed ReSpeaker 4-Mic Array Pi HAT is, as they say in the business, a nifty bit of gear. As well as four microphones, it has 12 LEDs, which can be used to indicate audio direction of arrival, or just to flash randomly and concerningly. It has GPIO and I2C connections, so that other devices can be daisy-chained to it, or it can stack directly on to Seeed's GrovePi hub, enabling even more sensors to be connected. It uses the AC108 codec, which at present isn't supported by the Raspbian kernel, so we need to install a custom one. Connect to the Pi, either by SSH or keyboard, and quit the Mycroft CLI. Run the following commands:

```
git clone https://github.com/respeaker/seeed-voicecard.git
cd seeed-voicecard
sudo ./install.sh
```

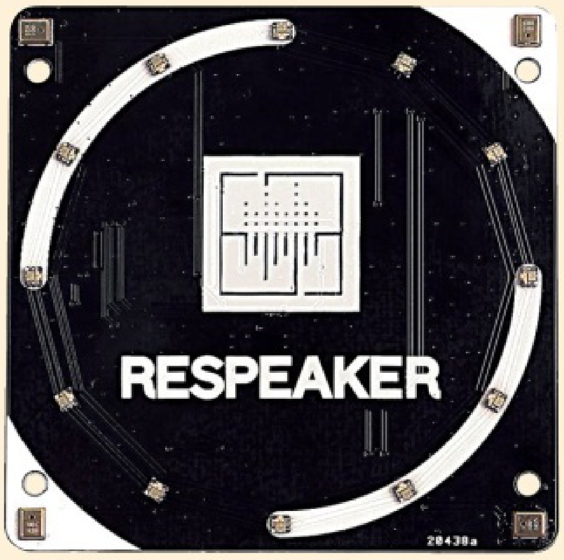
The install script chugs along for a while, and eventually you can reboot and activate the new kernel with `sudo reboot`. Reconnect if you were SSHing, then run `sudo raspi-config` to set up the audio. Select "7. Advanced Options," then "A4. Audio," then "1. Force 3.5mm jack." Then reboot and enjoy.

If you run into difficulties, you may need to install Pulseaudio and restart Mycroft's daemons with:

```
$ sudo apt install pulseaudio
$ ./start-mycroft.sh all restart
```

If it still doesn't work (and remember, if in doubt, a reboot never hurts), the Pulseaudio input device may need to be changed. List the devices with `pactl list sources` and then change the default to match the line beginning `Name` in the output, with:

```
pactl set-default-source "alsa_input.platform-soc_sound.
multichannel-input"
```



The ReSpeaker is suitably equipped with 12 LEDs and four microphones. No turntables, though.

ENSMARTENING YOUR HOME

We connected Mycroft to MPC Towers' aging central heating via openHAB, but facilities manager Dave took a dim view...

BESIDES BEING ABLE TO TELL you your IP address, Mycroft comes with a default set of skills, which enable it to answer vocal questions such as: "What time is it?"; "What's my location?"; "What's the weather like?"; and "What is the capital of Assyria?" Strangely, despite the Assyrian kingdom being no more, the latter question was the only one it got correct on our first attempt—apparently, Mycroft is not versed in *Monty Python*. These failings were due to the Wolfram Alpha fallback skill guessing our location and time zone from our IP address, specifically our local one beginning 192, which belongs to no one and nowhere, but which for some reason Mycroft resolves to New York. This conveniently derived the time to be three hours in the future for us. You can change your location by setting it in your Mycroft Home profile. You can also choose a username from here, to make logging in to the web portal easier.

Mycroft's core skills also include a basic "Hello World" example, which responds to its title; "How are you?"; and, rather graciously, "Thank you." This is intended to introduce people to programming their own skills. For fun and games, try asking it to sing a song or tell a joke. You can also ask it how to spell words, or to check stock prices.

One of the most popular skills for Mycroft is openHAB (Home Automation Bus), which is a platform for talking to all kinds of home appliances under a unified web interface. It can communicate with a multitude of different devices, including other smart-home platforms, such as Nest. Third-party add-ons can also be added via the Eclipse Marketplace, which enables us to control the popular Hive smart thermostat, and more.

CREATURES OF HAB-IT

You can install the openHAB server on your Picroft server or on a different machine. There's a pre-rolled image called openHABian that you can run on a different Pi—check it out at http://bit.ly/lxf249hab. On Ubuntu, or any Debian-like Linux, start by adding the required GPG key and repo, as follows. To make things easier, you can copy and paste this text from http://bit.ly/lxf249hab2:

```
$ wget -qO - 'https://bintray.com/user/downloadSubje
ctPublicKey?username=openhab' | sudo apt-key add -
```

techradar
72

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```
$ echo 'deb https://dl.bintray.com/openhab/apt-repo2 stable main' | sudo tee /etc/apt/sources.list.d/openhab2.list
```

Next, update the package lists and install openHAB:

```
$ sudo apt update
$ sudo apt install openhab2
```

You may also wish to install the openhab2-addons package, but add-ons can always be installed individually as needed from the openHAB web interface. Instructions for other distros and unstable releases can be found at http://bit.ly/lxf249hab2. Start openHAB and check that it's alive with:

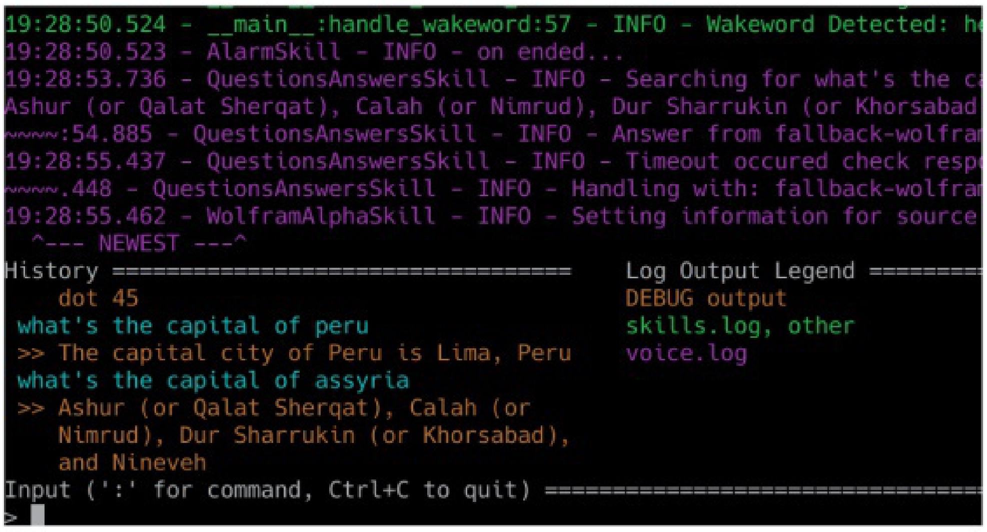
```
$ sudo systemctl start openhab2
$ systemctl status openhab2
```

JAVA IS A HARSH MISTRESS

If that didn't work, it could be due to your system missing a Java runtime. This is exactly what happened to us on our overburdened Picroft host, and we remedied it with:

```
$ sudo apt install oracle-java8-jdk
$ sudo systemctl start openhab2
```

We were then able to connect to the web interface by pointing our browser at http://192.168.0.23:8080 (admittedly, it took a couple of minutes). You'll want to change the part before 8080 to your openHAB host's IP address. Some initial configuration is required, but the wizard will walk you through it. Before you get really stuck in, do check out the thorough documentation at www.openhab.org to troubleshoot any niggles or find out more about the project—it's well worth a read.



```
19:28:50.524 - __main__:handle_wakeword:57 - INFO - Wakeword Detected: he
19:28:50.523 - AlarmSkill - INFO - on ended...
19:28:53.736 - QuestionsAnswersSkill - INFO - Searching for what's the ca
Ashur (or Qalat Sherqat), Calah (or Nimrud), Dur Sharrukin (or Khorsabad
~~~~:54.885 - QuestionsAnswersSkill - INFO - Answer from fallback-wolfra
19:28:55.437 - QuestionsAnswersSkill - INFO - Timeout occured check resp
~~~~.448 - QuestionsAnswersSkill - INFO - Handling with: fallback-wolfra
19:28:55.462 - WolframAlphaSkill - INFO - Setting information for source
  ^--- NEWEST ---^
History ==================================    Log Output Legend ========
    dot 45                                    DEBUG output
 what's the capital of peru                   skills.log, other
 >> The capital city of Peru is Lima, Peru    voice.log
 what's the capital of assyria
 >> Ashur (or Qalat Sherqat), Calah (or
    Nimrud), Dur Sharrukin (or Khorsabad),
    and Nineveh
Input (':' for command, Ctrl+C to quit) ================================
> 
```

Mycroft knows its onions, as well as its capital cities of fallen kingdoms.

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AUGMENTING OUR SKILL SET

We take a look at some more Mycroft skill-duggery and peer into the future of its development

MORE SKILLS can be found on the Mycroft Marketplace at https://market.mycroft.ai/skills (they're free). You can install them from there, verbally with something like "Hey Mycroft install coinflip," or manually at the Mycroft CLI. You can also install skills from the mycroft-skills GitHub repo. You'll also find excellent documentation on how to write your own there.

If you have a Spotify Premium account, there's a skill for that. You can either play tracks through other devices via Spotify Connect, or play them through whatever Mycroft's running on. Add the Spotify skill from the Marketplace; you should see a message like:

```
INFO - Will install ['mycroft-spotify'] from
the marketplace
```

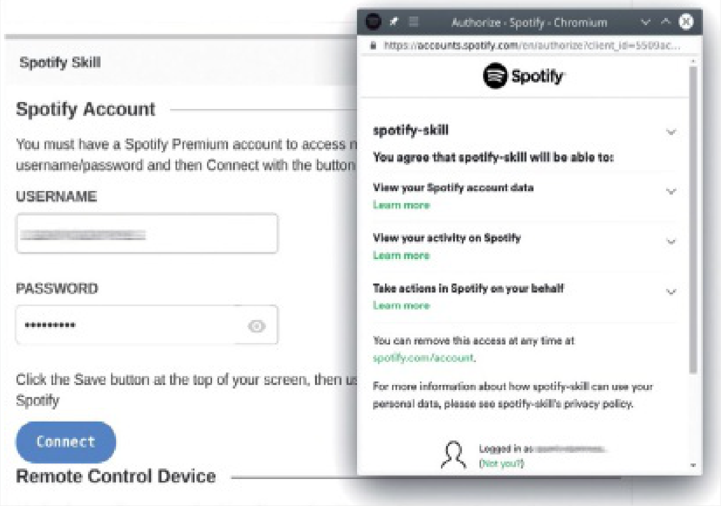
Before you can use the Spotify skill, you need to enter some credentials. In the links to the left of the Marketplace, navigate to "My Account → Profile." From here follow the "Skills" link at the top. Scroll down to "Spotify Skill," and enter your Spotify credentials. You're asked to bestow permissions on the Mycroft skill, and hopefully are greeted with a successful connection message. Don't forget to click "Save" at the top to yet again confirm your intent. This second confirmation is necessary because besides the API connection to Spotify, which is done by an OAuth, a further device authentication is necessary, which requires the skill to retain your Spotify credentials. See the documentation at http://bit.ly/lxf249spotify if you want to log in via Facebook, or generally find out more about the project.

You can now ask (or type) queries such as "What Spotify devices are available?"; "Show my playlists"; or "What song is this?" You can also issue demands, such as "Play discover weekly," "Play Get Free by Major Lazer," and "Stop playing." In the "Skills" configuration page in your Mycroft Profile, under "Remote Control Device" you can also change the default playback device, having Spotify stream to your Mycroft device.

Interestingly, Mozilla has just released, under a Creative Commons license, version 2.0 of the Common Voice dataset. This includes thousands of hours of matched audio and transcription in 18 different languages. It enables smaller projects access to an open dataset the like of which was previously only available to large companies.

Mycroft has its own anonymous voice-data collection feature, which you can opt into at the bottom of the "Basic Settings" on the "Mycroft Account" page. Looking ahead, the company will likely incorporate the Common Voice data into the collaboration it already has with the Mozilla DeepSpeech team (https://research.mozilla.org/machine-learning). One day, the goal is for DeepSpeech to be the default speech-to-text (STT) engine in Mycroft, but at present it requires considerable GPU power to run at adequate speeds. In future, this can be farmed out to the cloud, and indeed Mycroft already has a pool of GPU-heavy machines that can take care of the grunt work for ML-savvy Mycroft users. In the meantime, those made of really strong stuff may want to run their own DeepSpeech instance.

Earlier, we mentioned the Adapt intent parser. A new intent parser, Padatious—based on neural networks,



You must have a Spotify Premium account to access n… username/password and then Connect with the button…

Click the Save button at the top of your screen, then u… Spotify

https://accounts.spotify.com/en/authorize?client_id=5509ac…

You agree that spotify-skill will be able to:

View your Spotify account data

View your activity on Spotify

Take actions in Spotify on your behalf

You can remove this access at any time at spotify.com/account.

For more information about how spotify-skill can use your personal data, please see spotify-skill's privacy policy.

Logged in as [illegible] (Not you?)

The Spotify skill unfortunately won't pay your Spotify bill, but it does need some access to your account.

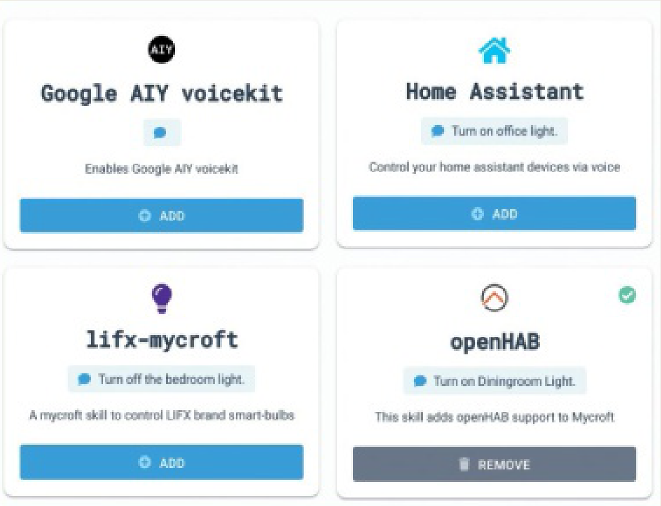
OPENHAB & OTHER PLATFORMS

We've barely scratched the surface of what openHAB is capable of, but it's just one of a number of platforms that can interoperate to one degree or another among themselves and, indeed, Mycroft.

For example, there's a *Minecraft* plugin for openHAB, so you can control actual devices in your house from the voxelated world of the game. It uses the popular SpigotMC plugin—look it up. You can also use openHAB to communicate with Nest devices and Amazon Echo.

There's also a Mycroft skill for controlling devices connected via the popular open-source Home Assistant platform (www.home-assistant.io), which can talk to all sorts of things such as Sonos audio systems, Alexa, Google Assistant, and Z-Wave devices. Like openHAB, Home Assistant has a smartphone app and offers a web interface.

Finally, Google Assistant has its own Python library. You can check out the sample code at http://bit.ly/lxf249python.



Enables Google AIY voicekit

Turn on office light.

Control your home assistant devices via voice

Turn off the bedroom light.

A mycroft skill to control LIFX brand smart-bulbs

Turn on Diningroom Light.

This skill adds openHAB support to Mycroft

The Mycroft add-ons page has a few IoT offerings, and there are several platforms outside of Mycroft.

© HTTPS://MYCROFT.AI/
3) HTTPS://GITHUB.COM/GOOGLESAMPLES/ASSISTANT-SDK-PYTHON/
4) HTTPS://GITHUB.COM/FORSLUND/SPOTIFY-SKILL

The more we look at it, the more that smile starts to take on a bit of an air of Clippy, the ever-helpful paperclip.

machine learning, and so on—is being developed by Mycroft. Where Adapt focuses on small groups of words, and tries to extract intent from them and the relationships between them, Padatious analyzes whole sentences. According to Mycroft, it's likely that Padatious will replace Adapt on some platforms, presumably ones with sufficient algorithmic horsepower.

Unlike closed-source assistants, we can be reasonably sure that Mycroft isn't listening to us at all times. More precisely, it is listening at all times, but any audio it picks up before the wake word is discarded. A corollary of this is that without the wake word, everything is discarded. The default engine that listens for the wake word is called PocketSphinx, but an alternative, Precise, is available (see http://bit.ly/lxf249precise). Precise is much more, uh, accurate, and is based on data collected from Mycroft users who have opted in to the data collection mentioned above.

At present, Precise is used only as a wake word detector. That's why you may become suspicious that Mycroft is so swift at responding to "Hey Mycroft," but all too often fails to make head nor tail of the noises that come afterward. That said, Precise is already being used elsewhere. A particularly interesting use case is Sickweather (www.sickweather.com). The site has been using it to track coughs and sneezes in public places, particularly on transport. With reliable data, and enough of it, the goal is to map and predict outbreaks of flu and other diseases—a veritable sickness forecast, hence the name. It's quite bizarre, we think, that a tool ostensibly focused so strongly on spoken words is finding use in the much more general field of hacking and croaking noises.

We trust Mycroft and Mozilla and everyone else working on this for the good of open source, but it's hard not to be a little creeped out at voice data being harvested. We already share far more than we should with the Internet through Facebook, Google, and friends. As voice becomes an ever more popular choice for interacting with the Internet and the Things connected to it in your home, surely we will be sharing more and more sensitive information with the services they connect to. That is troublesome if data turns out not to be sufficiently anonymized. And on that vaguely despondent note, we'll sign off, before the small army of Picroft machines we set up in the Maximum PC basement gets caught up in an awful feedback loop and destroys us all. ⏻

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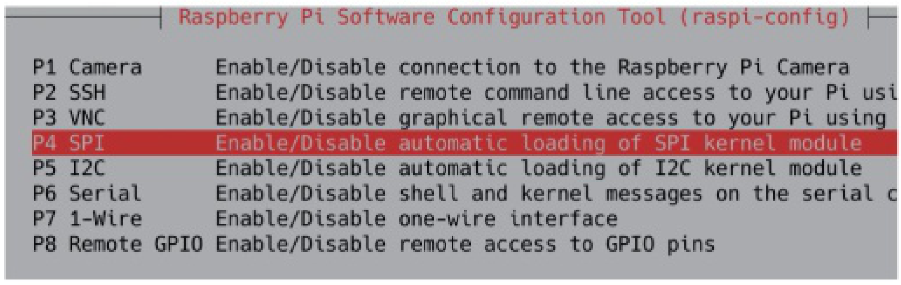
REVISITING THE RESPEAKER



```
Raspberry Pi Software Configuration Tool (raspi-config)

P1 Camera      Enable/Disable connection to the Raspberry Pi Camera
P2 SSH         Enable/Disable remote command line access to your Pi usi
P3 VNC         Enable/Disable graphical remote access to your Pi using
P4 SPI         Enable/Disable automatic loading of SPI kernel module
P5 I2C         Enable/Disable automatic loading of I2C kernel module
P6 Serial      Enable/Disable shell and kernel messages on the serial c
P7 1-Wire      Enable/Disable one-wire interface
P8 Remote GPIO Enable/Disable remote access to GPIO pins
```

1. ENABLE THE SPI BUS

The 12 LEDs on the ReSpeaker are connected over the Pi's SPI bus. This needs to be enabled before we can communicate using it. Run:

```
$ sudo raspi-config
```

Then select "Interfacing Options → SPI," and select "Enable SPI."

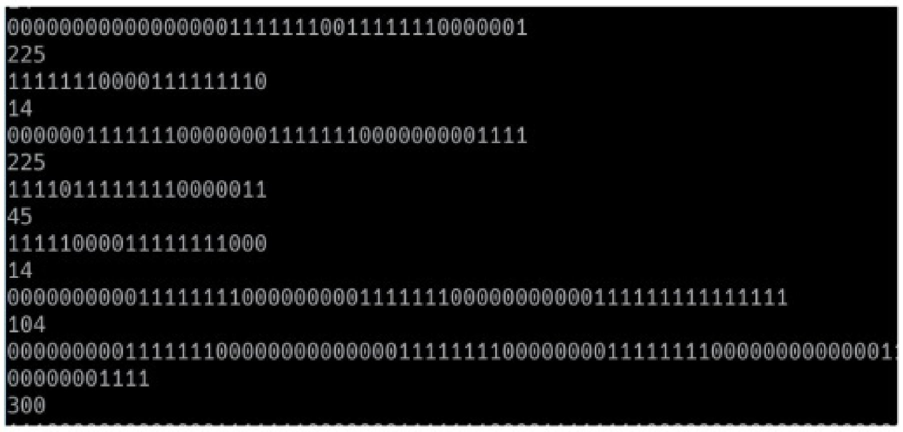
2. BLINK SOME LEDS

Next, grab the ReSpeaker code, and install some low-level Python dependencies:

```
$ git clone https://github.com/respeaker/4mics_hat.git
$ pip install spidev gpiozero
```

Run the demo "blinkenlights" with:

```
$ cd ~/4mics_hat/
$ python pixels_demo.py
```



```
0000000000000000011111110011111110000001
225
11111110000111111110
14
0000001111111000000011111110000000001111
225
11110111111110000011
45
11111000011111111000
14
000000000011111111000000000111111100000000000111111111111111
104
000000000111111100000000000000111111110000000011111110000000000000001
00000001111
300
```

3. HELP US!

We couldn't get the Direction of Arrival (DoA) code from the mic_array repo working. Changing `Queue` to `queue` in lines 4 and 25 of mic_array.py was a good start. Then this code displayed direction in the CLI, but did not light up our LEDs:

```
$ cd ~/mic_array/
$ python vad_doa.py
```

Maybe it will be working by the time you read this.

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TECH PORN

1 STANDING STILL

The Ghost has no fan—in fact, it has no moving parts. Using passive cooling, Shadow claims that it will never overheat—indeed, a quick pat down after several hours of testing revealed that it was indeed perfectly cool. The result of this is an almost totally silent device.

2 PLUGGED IN

At the rear, the Ghost has four USB ports for peripherals, HDMI 2.0 for connecting to a TV, a 3.5mm headphone jack, and an Ethernet port. It also has dual-band Wi-Fi, but given the nature of the device, it's best to stick to a wired connection for higher speeds.

3 SCALE MODEL

It's a tiny unit, weighing less than seven ounces, and standing only two inches tall. The Ghost is designed to occupy any space with minimal intrusion, the only indication that it's running at all being the single red LED that floods light out from underneath the unit.

Shadow Ghost

IF YOU LIKE TO keep abreast of tech news, you've probably heard of Shadow. A service operated by French company Blade, it allows users to access their own personal "Shadow," a virtual hosted environment on a server running Windows 10, which acts as a replacement for a pricey gaming PC. Shadow's servers are continually upgraded with the most recent hardware, ensuring that performance stays at the best possible levels. Users can download any games they own on to their Shadow, and play them at max settings, streaming input and feedback to and from the server.

With that in mind, we come to Blade's latest innovation: the Ghost. A replacement for the aging Shadow Box, the Ghost is designed to plug into a TV and bring high-end gaming to the couch, without the high-end price. It demands fast Internet to run properly, with Blade recommending 15MB/s as a minimum, but graphical fidelity is never in doubt; even if your Internet struggles with keeping the frame rate up, textures will always look glorious.

Given the Ghost's broadband-guzzling nature, some multiplayer games aren't best suited to running on it, but it shines at solo gaming. It can comfortably hit 60fps at 4K, and 144fps at 1080p. *Everspace* looks glorious on a 50-inch TV in high definition, with no latency issues on a 30MB/s connection. The Ghost comes with integrated Bluetooth, and uses just 5W of electricity—far less than the average gaming PC. **–CHRISTIAN GUYTON**

DEEP INTO STORAGE SPACE

At the edge of the final storage frontier, the universe's greatest storage system is about to unfold

WE ALL KNOW SSDS are coming to kill old spinning storage, but for many of us, a bank of HDDs still offers the capacity we need—8K footage, a mass of multi-megabyte photos, and who knows what other encyclopedic-level storage demands the discerning *Maximum PC* reader has?—without totally breaking the bank.

There's no doubt SSDs are catching up with their clunky spinning brethren on capacities, but the cost of a 4TB cutting-edge SSD drive would buy you nearly 30TB of spinning storage. If only there were a way to combine the storage space of old spinning drives with super-fast solid storage.... Well, say hello to Microsoft Storage Spaces. A modern solution for an ancient problem: Where to store all your old junk without enraging the other half. Storage Spaces are the Microsoft implementation of what the rest of the computing world generally calls storage pools.

It's an attempt to abstract away the messy workings of RAID, mirrors, and JBODs, and present to the user a simple unified pool of storage, with the option of adding caching drives, the ability to mix and match drives of varying capacities, the bonus of device redundancy, and an easy way to manage your spaces.

It seems like the perfect solution, so why isn't everyone using storage spaces? Well, Microsoft being Microsoft, it went and had to try to hobble a useful system for standard Windows 10 users. So, we're here not only to explain how to get the most from your storage spaces, but also put back the missing functionality, no matter what Microsoft might want. Let's get exploring....

ANTHONY HOWES

Everyone's looking for ways to make their busy lives easier and simpler. Because laziness is the true mother of invention, and the world is full of sysadmins who don't want to be hassled by failing drives, there came a solution: Storage Spaces. These are a way of creating virtual drives from a storage pool of real hardware storage, no matter what form that hardware takes.

No longer do you need to have a mess of multiple drives. No longer do you have to mess with RAID systems. With Windows 10, you can just pile together a bunch of storage, and have it appear as a single storage space that comes with a bunch of additional friends with benefits.

Storage Spaces is included with the consumer release of Windows 10; the server product Storage Space Direct has a few additional features, but is only available on Windows Server 2012/16/19. By and large, the extra features are aimed at enterprise and data center type usage. One feature, however, is support for SSD tiered storage and write-back cache—essentially, it enables you to provision a dedicated SSD drive(s) to cache a larger Storage Space. It appears that Microsoft removed GUI-based support in the consumer version of Windows 10, but it is possible to use PowerShell to manually specify a drive. So, we'll look at this once we've covered the basics.

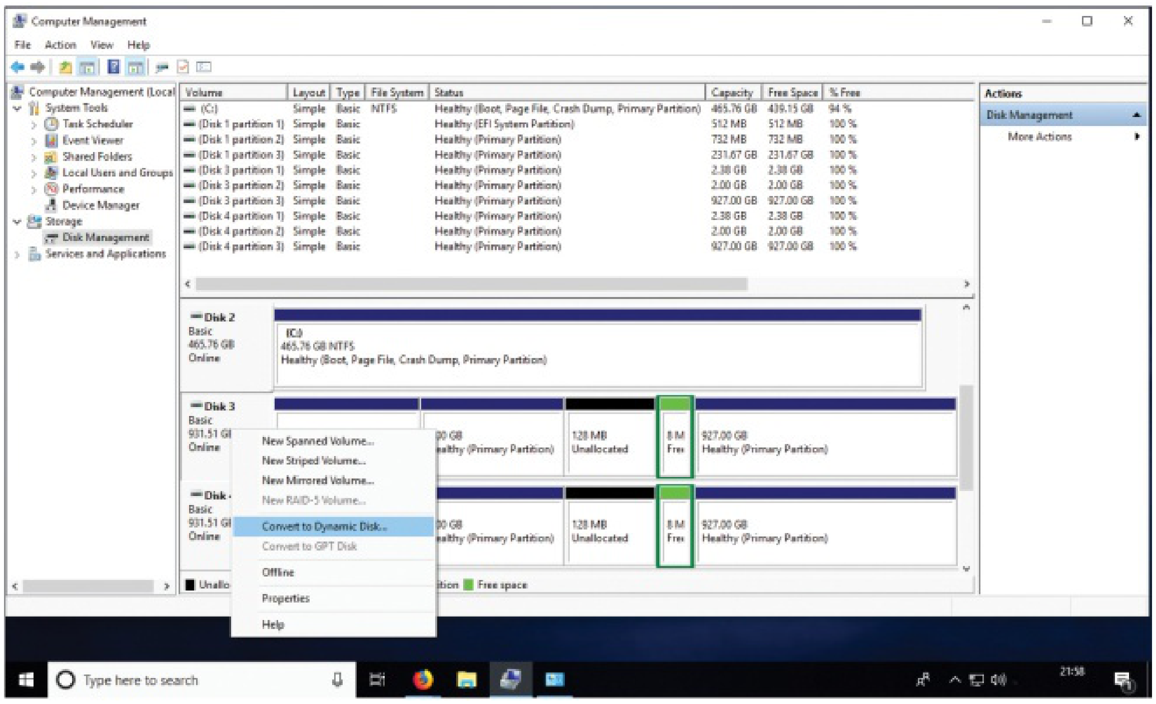
We're going to look at your options for configuring Storage Spaces; part of that examines how the different options work for combining physical drives together into what Microsoft calls a storage pool. The combinations can get pretty varied, especially when you factor in expanding pools, and how virtual Storage Spaces can be "provisioned" across them. We want to manage pools, replacing drives, rebuilding them, and optimizing when needed, while we also look at using an SSD to enhance write performance. And, of course, we can throw a few benchmarks at our pool to see how it performs.

THE SCIENCE STUFF

Before we get stuck in with provisioning a few drives, we have to do some theory on how pools are created and why they exist, because it'll save some head scratching, and having to rebuild your Spaces when you realize you've not done an optimal job. If you're hot to trot on RAID and the like, you might want to skip ahead. As we've alluded to, Storage Spaces came about from admin demand for simplifying—aka abstracting away complexity—storage management. It's not hard to imagine. You have a data center full of server racks, packed with spinning drives that are continually failing. You not only want a system that can prevent data loss when drives fail, but also a system that simplifies managing all this storage as a single block, or at least a series of blocks.

Taking the first part of that problem, one of preventing data loss, you want to add redundancy to your storage: If one drive fails, you don't lose data, and everything can continue as if nothing bad happened. Storage Spaces, and traditional computing, offers two options: drive mirroring and parity storage, aka RAID.

Mirroring is the easiest to understand. The basic configuration is when you have two identical drives, and the same data is written to both—if one drive fails, you have a spare copy on the other. Simple? Well, mirroring can get more complex: Imagine



Volume	Layout	Type	File System	Status	Capacity	Free Space	% Free
(C:)	Simple	Basic	NTFS	Healthy (Boot, Page File, Crash Dump, Primary Partition)	465.76 GB	439.15 GB	94 %
(Disk 1 partition 1)	Simple	Basic		Healthy (EFI System Partition)	512 MB	512 MB	100 %
(Disk 1 partition 2)	Simple	Basic		Healthy (Primary Partition)	732 MB	732 MB	100 %
(Disk 1 partition 3)	Simple	Basic		Healthy (Primary Partition)	231.67 GB	231.67 GB	100 %
(Disk 3 partition 1)	Simple	Basic		Healthy (Primary Partition)	2.38 GB	2.38 GB	100 %
(Disk 3 partition 2)	Simple	Basic		Healthy (Primary Partition)	2.00 GB	2.00 GB	100 %
(Disk 3 partition 3)	Simple	Basic		Healthy (Primary Partition)	927.00 GB	927.00 GB	100 %
(Disk 4 partition 1)	Simple	Basic		Healthy (Primary Partition)	2.38 GB	2.38 GB	100 %
(Disk 4 partition 2)	Simple	Basic		Healthy (Primary Partition)	2.00 GB	2.00 GB	100 %
(Disk 4 partition 3)	Simple	Basic		Healthy (Primary Partition)	927.00 GB	927.00 GB	100 %

Disk 2
Basic
465.76 GB
Online
(C:)
465.76 GB NTFS
Healthy (Boot, Page File, Crash Dump, Primary Partition)

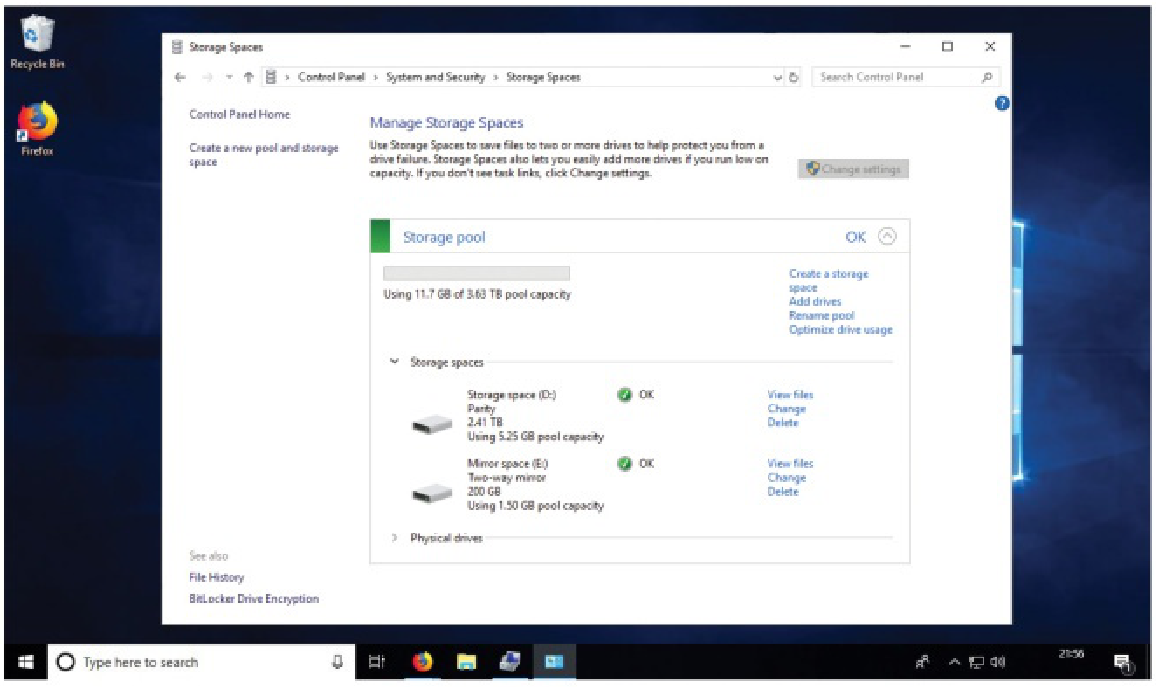
Ensure you clear any drives before you try to add them to a storage pool.

SAME SIZE, BUT DIFFERENT

Can you use drives of different sizes? Yes, but no. Clear as mud—just how we like it. The short and basic answer is that in any parity or mirrored pool, you can use any size of drives you like, but the maximum capacity of the pool is determined by the smallest drive.

Take a mirror consisting of a 1TB and 2TB drive—the maximum mirrored capacity is 1TB; the 2TB drive is limited to 1TB of storage. For a parity array, take a 4TB, 4TB, and a 6TB pool of drives. The overall capacity would be 12TB, because the 6TB is limited to the 4TB of the two smaller drives, though space available for storage would be 8TB, as a third is reserved for parity data, as we've explained.

If the occasion arises, you can more cleverly match your different-sized drives in mirrors to maximize your space. For example, if you had two 4TB and two 6TB drives, you'd match up one 4TB and one 6TB to create one side of a 10TB mirror, and the remaining two drives on the other.


Recycle Bin
Firefox
Storage Spaces
Control Panel > System and Security > Storage Spaces
Search Control Panel
Control Panel Home
Create a new pool and storage space

Manage Storage Spaces

Use Storage Spaces to save files to two or more drives to help protect you from a drive failure. Storage Spaces also lets you easily add more drives if you run low on capacity. If you don't see task links, click Change settings.

Change settings
Storage pool
OK

Using 11.7 GB of 3.63 TB pool capacity

Create a storage space
Add drives
Rename pool
Optimize drive usage
Storage spaces

Storage space (D:)
Parity
2.41 TB
Using 5.25 GB pool capacity
OK

Mirror space (E:)
Two-way mirror
200 GB
Using 1.50 GB pool capacity
OK

View files
Change
Delete
Physical drives
See also
File History
BitLocker Drive Encryption
Type here to search

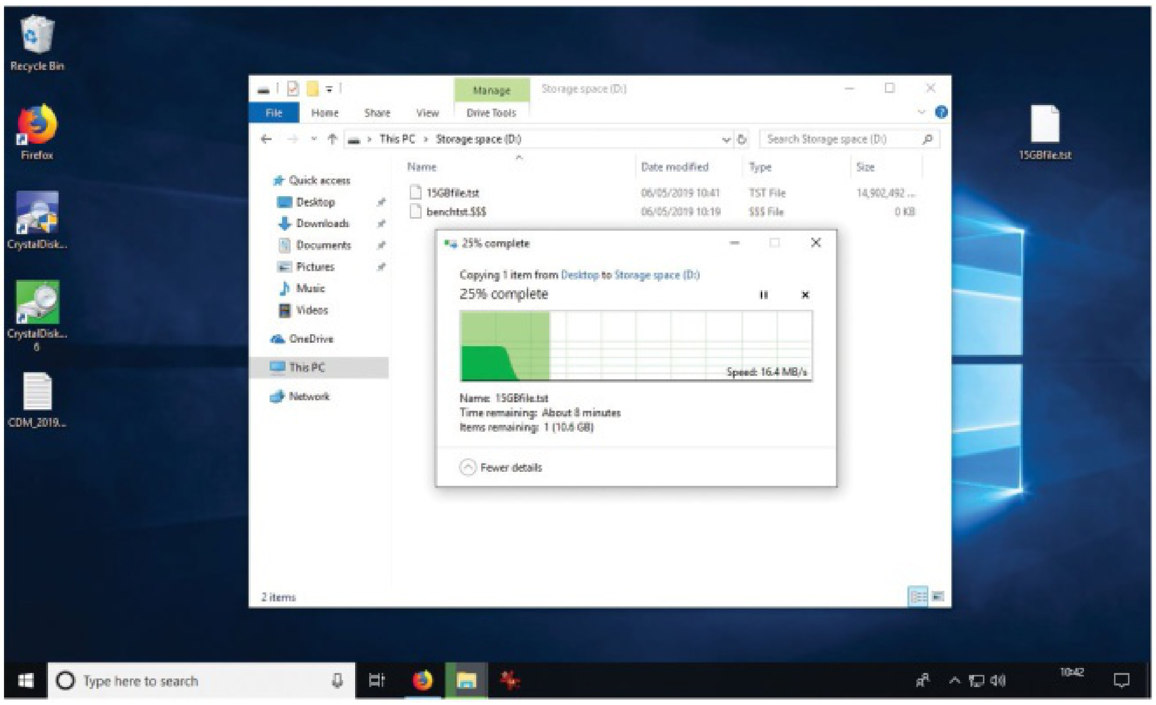
You can assign multiple Storage Spaces, even if they're bigger than the physical storage.

each side of the mirror as a storage "column." Storage Spaces enable you to combine multiple drives together in each storage column. One column mirrors the other, but with multiple drives, which is handy when you want to expand an existing mirror with more drives. Storage Spaces have also extended the idea of the basic mirror to a three-way mirror, so rather than just two mirror storage columns, you have three. The theory being the window of failure on a complex two-way mirror is big enough to warrant additional redundancy in the system.

The issue here is that a standard mirror wastes space—50 percent of your total storage is lost as redundancy. A three-way mirror is even worse, with 66 percent "lost" to redundancy. Isn't there a more efficient option?

Enter parity storage, also known as RAID (Redundant Array of Inexpensive/Independent Drives). Avoiding going into the actual math, parity uses a logic trick—it's used in error checking, too—that means that by comparing two bits being stored, you generate a third parity bit. These are stored over your base three "parity" drives—the minimum number required. Bit one is written to drive one, bit two to the second drive, and the parity bit to the third drive. If any one drive now fails, you can get your data back by reversing the parity creation process, called rebuilding.

From this basic system, you should hopefully see how you can build it up to writing two bytes of data and then a parity byte—the actual amount of data is variable and typically called a "stripe," as data blocks and parity blocks are striped across the array of parity drives. Four, five, or more drives can be added, and the data and parity data is simply spread across the drives. In this case, 33 percent of your total storage is used as redundancy, so it's


Recycle Bin
Firefox
CrystalDisk...
CrystalDisk... 6
CDM_2019...
15GBfile.tst
Manage
Storage space (D:)
File
Home
Share
View
Drive Tools
This PC > Storage space (D:)
Search Storage space (D:)
Quick access
Desktop
Downloads
Documents
Pictures
Music
Videos
OneDrive
This PC
Network

Name	Date modified	Type	Size
15GBfile.tst	06/05/2019 10:41	TST File	14,902,492 ...
benchtst.$$$	06/05/2019 10:19	$$$ File	0 KB

25% complete

Copying 1 item from Desktop to Storage space (D:)
25% complete
Speed: 16.4 MB/s

Name: 15GBfile.tst
Time remaining: About 8 minutes
Items remaining: 1 (10.6 GB)

Fewer details
2 items
Type here to search

We found Microsoft parity-based Storage Spaces to be hot garbage, performance-wise.

© MICROSOFT WINDOWS 10

SOLID STATES

Windows offers two features to accelerate Storage Space performance: write-back cache and SSD tiers. On the consumer release of Windows 10, these can only be implemented through PowerShell when the Space is originally created. We failed to add an SSD tier to a parity array of HDDs, but did have success with a single SSD and a simple array, plus a mirrored SSD and HDD array. We'll look at how to create both.

We're starting the process from a blank slate, so first remove your Spaces and pools. We'll be using PowerShell (the fifth Ninja Turtle), so search for that, and run it in Administrator mode. Step one is to create a variable that stores the available blank drives; run this command without `$disks =` to see the output. We can then create our pool from that list.

```
$disks = Get-PhysicalDisk -CanPool
$True
```

```
New-StoragePool -PhysicalDisks $disks
–StorageSubSystemFriendlyName
"Windows Storage*" -FriendlyName
"Pool"
```

Next, we create two more variables that store the details for what will be our SSD tier and HDD tier for drives.

```
$ssd = New-StorageTier
-StoragePoolFriendlyName "Pool"
-FriendlyName SSDTier -MediaType SSD
```

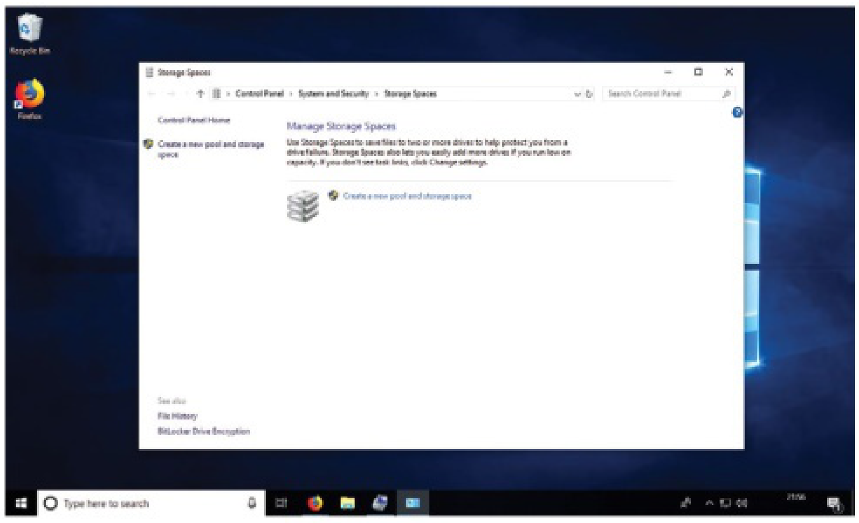
```
$hdd = New-StorageTier
-StoragePoolFriendlyName "Pool"
-FriendlyName HDDTier -MediaType HDD
```

Finally, we create a Storage Space with the `New-VirtualDisk` command—you'll need to change the `-StorageTierSizes` values to suit your devices.

```
New-VirtualDisk
-StoragePoolFriendlyName "Pool"
-FriendlyName MySpace -StorageTiers
$ssd, $hdd -StorageTierSizes 400GB,
3000GB -ResiliencySettingName Simple
-WriteCacheSize 10GB
```

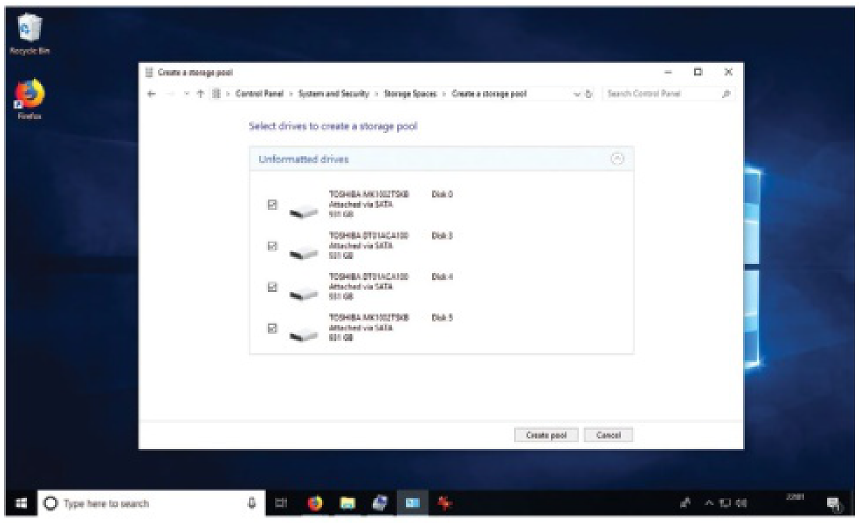
Open the Manage Spaces control panel and you'll see a new unformatted space. You can format and manage it within the GUI from here. If you have two SSDs, you're in luck, because you can create a cached mirror space. Repeat the last set of commands, but this time around, simply enable the `ResiliencySettingName` as `Mirror`. We assume that if you had three SSDs, you'd be able to enable parity.

```
New-VirtualDisk
-StoragePoolFriendlyName "Pool"
-FriendlyName MySpace -StorageTiers
$ssd, $hdd -StorageTierSizes 400GB,
2000GB -ResiliencySettingName Mirror
-WriteCacheSize 10GB
```


Storage Spaces
Control Panel › System and Security › Storage Spaces
Search Control Panel
Control Panel Home
Create a new pool and storage space
Manage Storage Spaces
Create a new pool and storage space
See also
File History
BitLocker Drive Encryption
Type here to search

Use Storage Spaces to save files to two or more drives to help protect you from a drive failure. Storage Spaces also lets you easily add more drives if you run low on capacity. If you don't see task links, click Change settings.

The main Storage Spaces control panel before anything is created.


Create a storage pool
Control Panel › System and Security › Storage Spaces › Create a storage pool
Search Control Panel
Select drives to create a storage pool
Unformatted drives
Create pool
Cancel
Type here to search

☑ TOSHIBA MK1002TSKB Attached via SATA 931 GB Disk 0
☑ TOSHIBA DT01ACA100 Attached via SATA 931 GB Disk 3
☑ TOSHIBA DT01ACA100 Attached via SATA 931 GB Disk 4
☑ TOSHIBA MK1002TSKB Attached via SATA 931 GB Disk 5

A storage pool isn't much use without a few drives to play with.

more efficient than a mirror, especially for a larger number of drives.

In the old parlance, this would have been called a RAID 5 system—striped parity—and it can deal with a single drive failing in the array. A dual-parity option provides parity redundancy, which means two drives can fail with no loss of data; that would have been called RAID 6. Why would you need parity redundancy? Technically, the rebuild time of an array using drives larger than 1TB is so long that another drive could fail, so RAID 6 was recommended in these cases.

A final type of array is just referred to as "simple." This offers no redundancy—it's simply pooling drives for storage.

A feature of pooling hard drives that shouldn't be overlooked is the performance through parallel access. Typically, this only improves reads, but it can enhance writes, because the drive controller can queue up parallel reads across the array for both mirrored and parity spaces without additional cache.

The main takeaway here is that drives can be added and removed relatively safely without losing your data, though there is always a "rebuild" time that impacts performance while the parity data is recreated. Windows provides a "optimize" option that should be run when a Space is expanded or reduced. We'll delve into handling Storage Spaces now.

GIVE ME SPACE!

Now we know the basics of what goes on behind the scenes with Storage Spaces, let's move on to how you can set one up within Windows 10 Pro. As we've hinted at, a Storage Space is a "virtual drive," made up of many other drives grouped in a storage pool. This means that Windows can build a Space from different types of drives running over ATA, SATA, SAS, USB, or NVMe. It just requires the minimum number of drives for the type of Space you request. You don't even need the full physical capacity available that you request, although Windows throws up warnings as the Space fills up.

For our example, we're going to use four 1TB HDDs in various configurations, and we'll attempt to attach an SSD as a write-back cache via the PowerShell. To kick off, you need to hook up your drives. Once back in Windows, check the drives have been recognized and are blank—ours had a mix of GPT, Dynamic, and previous mirrored arrays on them.

In the search tool, type "diskmgmt" and hit Enter to open the Disk Management console. You have to use your own common sense here to identify your new drives—these need to be cleared before they can be added to a storage pool. Right-click any partitions and select "Delete Volume"—check the contents with "Open" before destroying your data.

With cleared drives, we can move to creating a pool. In search, type "Storage" and select "Manage Storage Spaces." As none exist, click the link to "Create a new pool and Storage Space." It presents you with a list of suitable drives that can be added to a storage pool, which should be your blank drives. Select the drives you want to add, and click the "Create pool" button. If you get an error about not being able to complete the operation, try rebooting Windows—we had this issue a couple of times.

Here's where you select the options for your new Space: name, drive letter, and filesystem. For filesystem, you should only have NTFS available; Microsoft is developing REFS (REsilient File System), but it's aimed at data center/enterprise applications with checksumming features over mirrored arrays and rapid block re-allocation for virtualization. It appears Microsoft isn't rolling this out to consumer Windows users—yet.

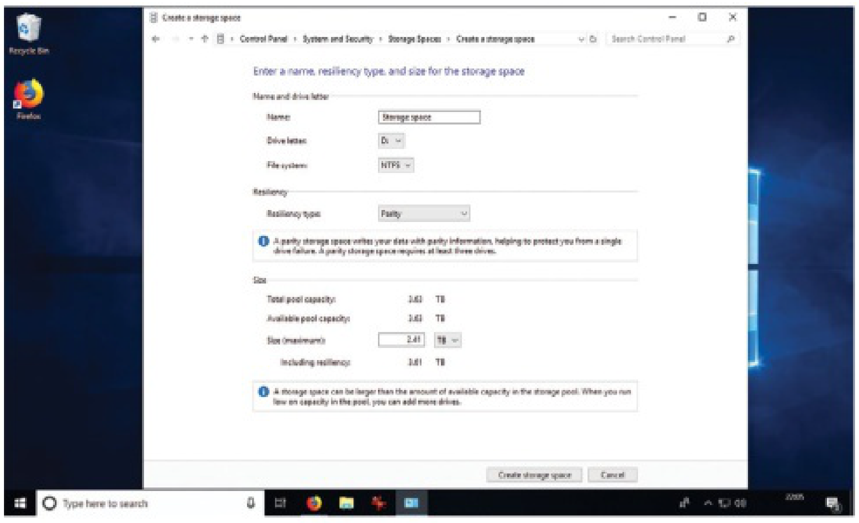
"Resiliency" refers to the simple, mirror, and parity types we covered earlier. Depending on the type you choose, it alters the overall storage capacities below. As it's a virtual storage system, you can over-allocate the physical space, the expectation being that you'll add more storage when it's required. Once you're happy, click "Create storage space."

At this point, we're done. Yay! Stop reading, go home. The new Space appears under "This PC"—or whatever Microsoft is calling your PC this year—as a new monolithic drive. You can benchmark, install to, copy from it, and so on, like any normal drive. But it's not a normal drive. Re-open the Storage Space, and you'll see a host of new options, and the status of the overall pool and individual drives.

Because this is all virtualized, you can create additional Storage Spaces within the same pool. Even if the total space exceeds that physically available, Windows doesn't care—it's like that these days. To make any changes, you need to click the Administrator "Change settings" button. As you should see, you're able to create additional Spaces, which takes you through the previous procedure.

You're able to change an existing Storage Space in terms of its name, drive letter, and overall capacity—its resiliency is fixed. Notice how you don't add drives to

As it's a virtual storage system, you can over-allocate the physical space, the expectation being that you will add more storage when it's required.


Create a storage space
Control Panel › System and Security › Storage Spaces › Create a storage space
Search Control Panel
Create storage space
Cancel
Type here to search

Enter a name, resiliency type, and size for the storage space

Name and drive letter

Name: Storage space

Drive letter: D:

File system: NTFS

Resiliency

Resiliency type: Parity

A parity storage space writes your data with parity information, helping to protect you from a single drive failure. A parity storage space requires at least three drives.

Size

Total pool capacity: 3.63 TB

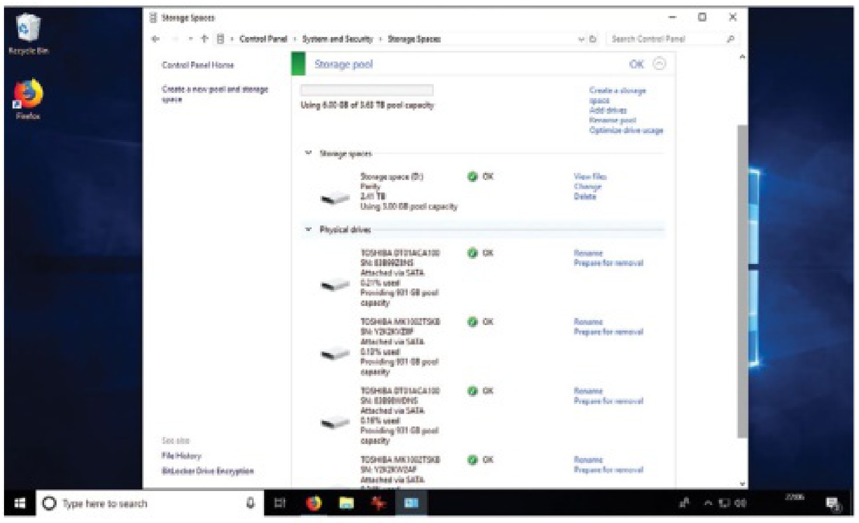
Available pool capacity: 3.63 TB

Size (maximum): 2.41 TB

Including resiliency: 3.61 TB

A storage space can be larger than the amount of available capacity in the storage pool. When you run low on capacity in the pool, you can add more drives.

Specify a Storage Space's resiliency and capacity in the control panel.


Storage Spaces
Control Panel › System and Security › Storage Spaces
Search Control Panel
Control Panel Home
Create a new pool and storage space
Create a storage space
Add drives
Rename pool
Optimize drive usage
View files
Change
Delete
Rename
Prepare for removal
See also
File History
BitLocker Drive Encryption
Type here to search

Storage pool OK

Using 6.00 GB of 3.63 TB pool capacity

Storage spaces

Storage space (D:) OK
Parity
2.41 TB
Using 3.00 GB pool capacity

Physical drives

TOSHIBA DT01ACA100 OK
Attached via SATA
0.21% used
Providing 931 GB pool capacity

TOSHIBA MK1002TSKB OK
Attached via SATA
0.12% used
Providing 931 GB pool capacity

TOSHIBA DT01ACA100 OK
Attached via SATA
0.18% used
Providing 931 GB pool capacity

TOSHIBA MK1002TSKB OK
Attached via SATA

Once a pool and Space have been created, monitor them here.

a Storage Space; this is restricted to the storage pool. So, if you were expanding your capacity, you'd add a drive to the pool, and increase the available capacity to any Storage Spaces that deserve it. After adding to the capacity of a Storage Space, you should run the "Optimize drive usage" feature—this reallocates data and parity stripes for efficiency over the drives; though be aware that this reduces performance while it's being run.

The "Physical drives" section lists the status and options for all the attached drives. If a drive should fail, or you're planning to upgrade a drive, or for whatever reason need to remove a drive from the storage pool, you need to click "Prepare for removal." Make a note of the "Model" and "SN" (serial number), so you remove the correct physical drive. Data is moved off the drive, and when finished, a "Remove drive" button appears. The drive won't appear back in Explorer, because it's still formatted as a storage pool device; you need to wipe it through Drive Manager, as we did to prepare the drives at the beginning.

Finally, if you decide Storage Spaces aren't for you, removing them is no harder than clicking the "Delete" button—just make sure you remove all Storage Spaces before trying to delete the pool. In fact, you can't even see the "Delete" option if there's a Storage Space in use. To reclaim your drives, remove all the Storage Spaces, then you can remove the pool.

That's the easy way to build a straight Storage Space from a storage pool via the GUI, but it doesn't take full advantage of any SSDs, or enable you to increase the write-back cache from the default 1GB. For this, you need to shift to the PowerShell—see the "Solid States" boxout for exactly how that works. Our benchmarks show that it has a dramatic increase to a simple array, boosts mirror performance, and certainly helps the garbage performance that Storage Space parity arrays offer.

PERFORMANCE RESULTS

For our testing, we used a bank of four 1TB Toshiba 7,200rpm SATA hard drives in a number of Storage Space configurations: Simple, Mirrored, and Parity. Alongside this we ran two mismatched 480GB SSD SATA drives. We're only interested in an overview of performance, so we relied on CrystalDiskMark 6 for our results. We even created a couple of Spaces through the Spaces GUI to see what it would make of them, and if the PowerShell route was actually superior.

CONFIGURATIONS			*BENCHMARK RESULTS (MB/s)*			
Space Type	**HDD Tier**	**SSD Tier**	**Seq R/W**	**4K Q8T8**	**4K Q32T1**	**4K Q1T1**
None	*1x* 1TB HDD	None	156.9/156.8	1.39/1.11	1.44/1.12	0.59/1.16
Simple	*4x* 1TB HDD	None	164/170	1.70/1.43	1.71/1.54	0.65/1.57
Simple	*4x* 1TB HDD	*2x* SSD	1,115/1026	587/627	244/195	34/98
Mirror	*4x* 1TB HDD	None	176/164	2.38/1.34	2.38/1.24	0.65/1.37
Mirror	*4x* 1TB HDD	*2x* SSD*	216/284	10.7/73.9	10.5/46.7	1.23/42.9
Mirror	*4x* 1TB HDD	*2x* SSD	565/514	462/314	249/99.9	35.7/72.5
Parity	*4x* 1TB HDD	None	313/65.1	3.97/0.48	3.98/0.38	0.65/0.46
Parity	*4x* 1TB HDD	*2x* SSD*	307/238	4.07/0.29	4.16/1.77	0.90/33.5

**GUI-created Storage Space*

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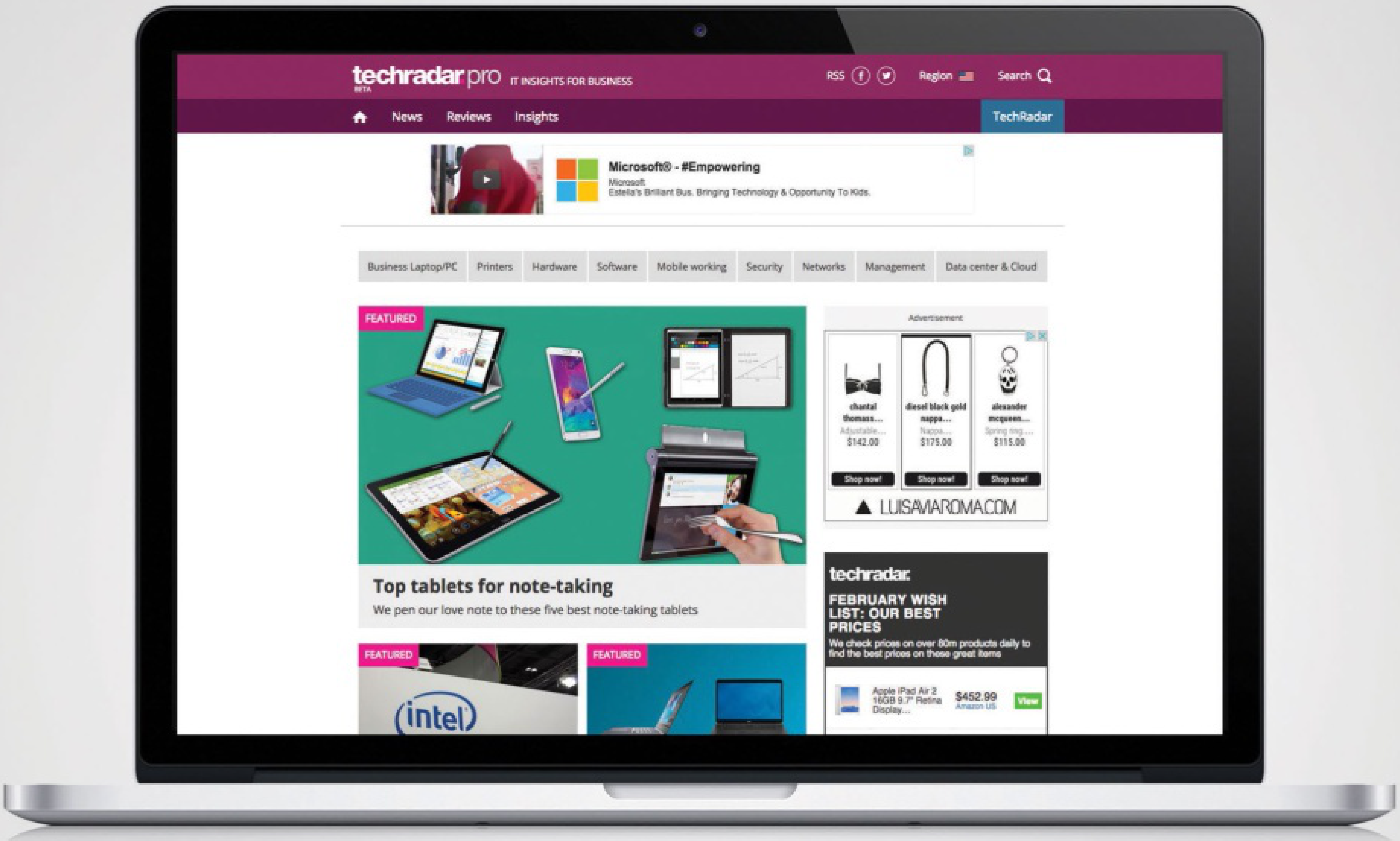
IT INSIGHTS FOR BUSINESS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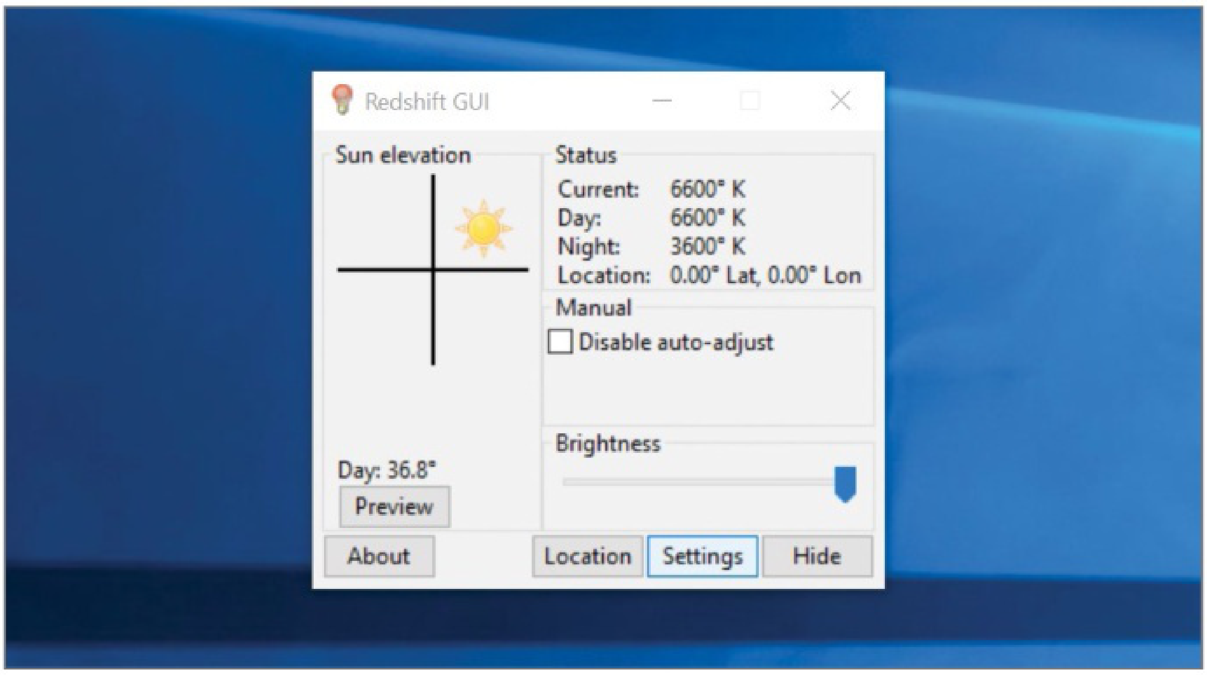
HOW TO

STEP-BY-STEP GUIDES TO IMPROVING YOUR PC

TIP OF THE MONTH


Redshift GUI

Sun elevation

Day: 36.8°

Status

Current: 6600° K

Day: 6600° K

Night: 3600° K

Location: 0.00° Lat, 0.00° Lon

Manual

☐ Disable auto-adjust

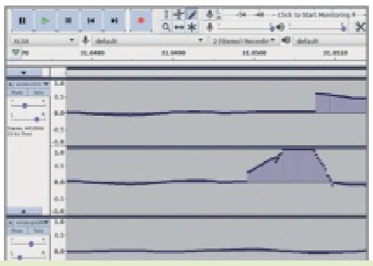
Brightness

© MICROSOFT WINDOWS 10

CONTROL BRIGHTNESS IN WINDOWS 10

Like us, you might be frustrated by the removal of brightness settings in Windows 10. As a workaround, try downloading RedShiftGUI, a free piece of software that allows for straightforward manual brightness adjustment. As an added bonus, it features a more in-depth version of Win 10's Night Mode, altering color temperature automatically based on the time of day to make late-night browsing easier on the eyes.

MAKE – USE – CREATE



58
Advanced audio recording and editing in Audacity

62
Create a Pi-based information radiator with DAKboard

70
An affordable media center—the perfect living-room rig

CHRISTIAN GUYTON
STAFF WRITER

MEDIA MASTERS

Media center PCs are weird. Sure, the idea of hooking up a mini computer to your television for some low-level gaming or movie streaming sounds great on paper, but these PCs compete with everything from the Xbox One to Samsung's latest smart TV and beyond. This month's "Build It" had us scratching our heads and closely examining pricing trends on computer components. Our research revealed one damning piece of evidence: If you're going high-end, splurging on expensive GPUs and processors, you'll likely be able to save money on your build—but it's near-impossible to put together a good ultra-low-end PC for good value.

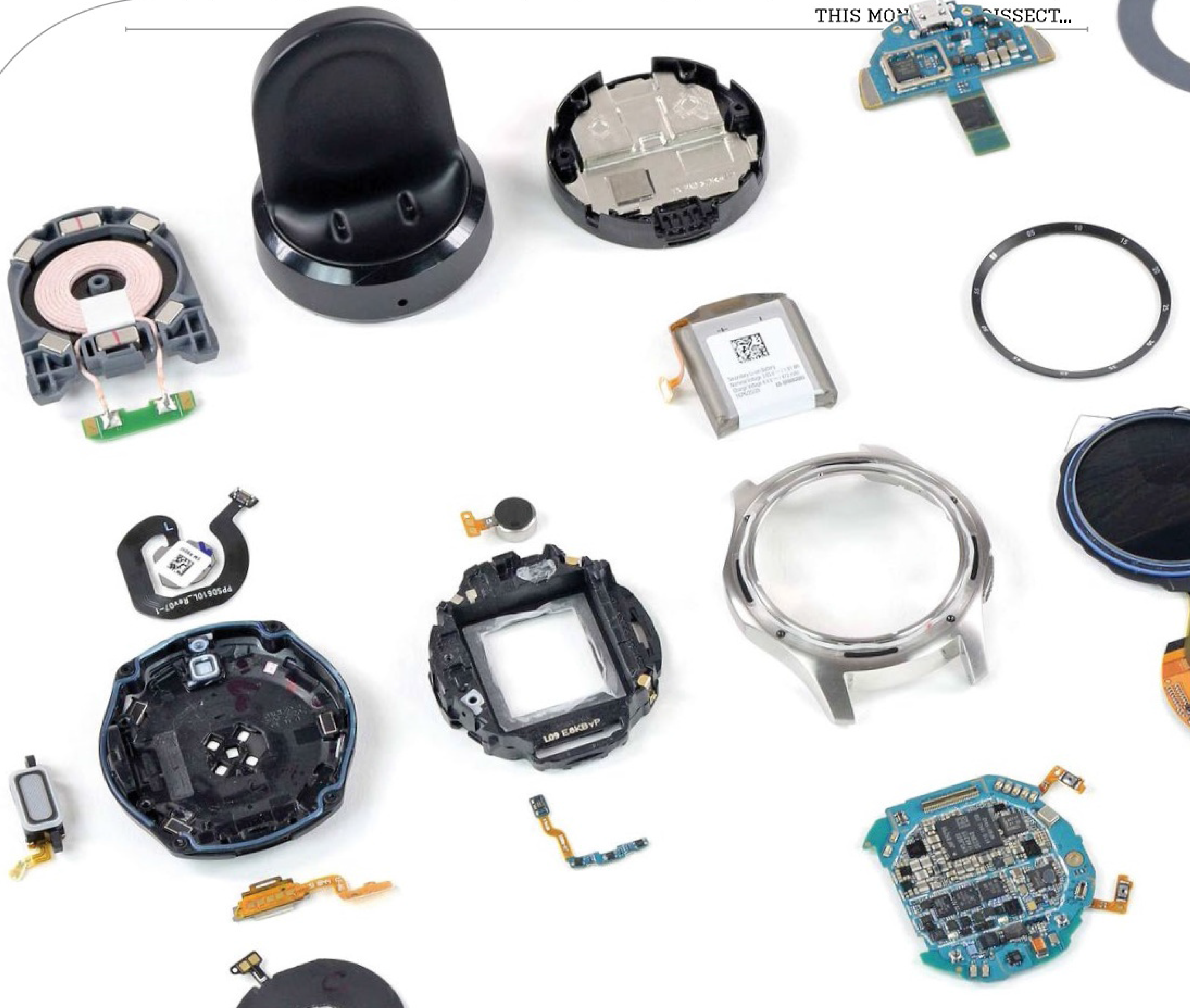
It's hard to judge the worth of these computers when you look at the numbers. If you're doing it yourself, you're almost inevitably going to end up paying more than you would for a pre-built media center system. Manufacturers such as AcePC and Beelink are putting out tiny computers for a fraction of the price of a self-built system, but they come with a trade-off of power and customizability. We can't make the decision for you—if you're considering getting a media center for your home, you'll need to do the homework yourself.

↘ submit your How To project idea to: comments@maximumpc.com

IFIXIT presents:

AUTOPSY

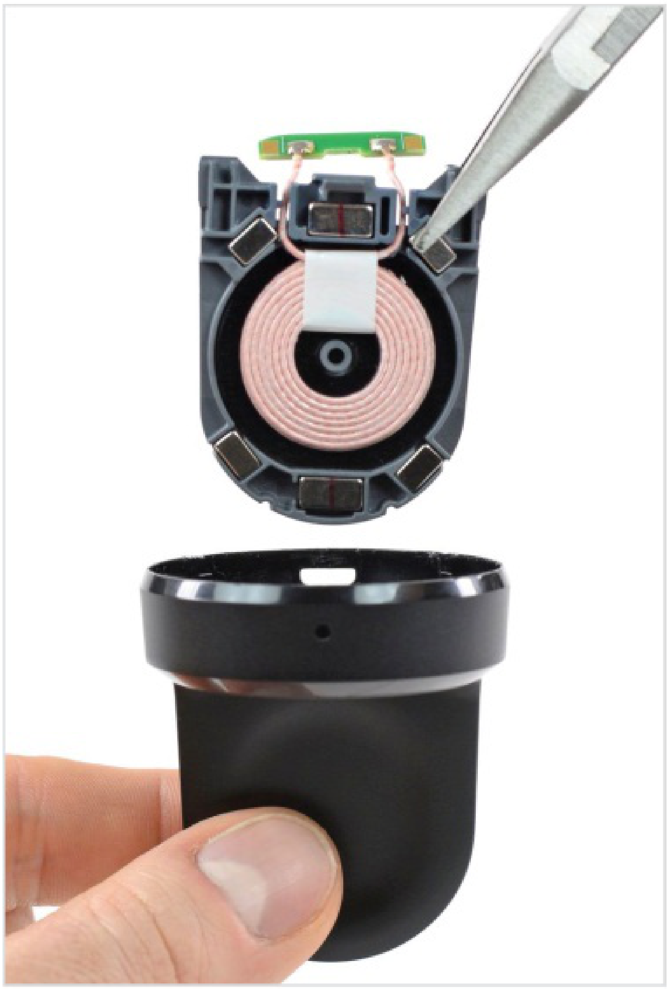
THIS MON ISSECT...



About iFixit

iFixit is a global community of tinkerers dedicated to helping people fix things through free online repair manuals and teardowns. iFixit believes that everyone has the right to maintain and repair their own products.
To learn more, visit www.ifixit.com.

Samsung Galaxy Watch



This charger's layout could be similar to the Gear S3 charging dock, which provides 700mA of output current at 5V.

We can pop out the 3.85V battery—with its 472mAh offering 1.81Wh—with our finger.

BACKGROUND

In the age of Galaxy smartphones and tablets, Samsung adds a Galaxy Watch to its universe. There was already some gear floating in space, forming a belt around the Samsung sun, but a few months ago, this new celestial body emerged. Today we'll go where no tinkerer has gone before, and probe the depths of this timepiece with a teardown.

MAJOR TECH SPECS

- 1.3-inch (33mm) circular Super AMOLED with 360×360 display (1.2-inch/30mm on the smaller 42mm version)
- Dual-core, 1.15GHz Exynos 9110 processor
- 1.5GB RAM and 4GB internal memory (768MB RAM for the Bluetooth version)
- Wireless charging and 5ATM IP68 water resistance
- 472mAh battery (270mAh for the 42mm version)

KEY FINDINGS

- A quick survey reveals twin mechanical buttons on one side, with a small hole for the mic. On the far side, we spot three holes for the loudspeaker. There's also a heart rate sensor cluster at the bottom, plus a small opening on the rear, possibly for a proximity sensor or pressure valve.
- The standardized 22mm arms are easy to detach, and reveal access to a five-pin port. Is that a USB+1 for emergency wired charging and service? Equipped with our Precision Bit Driver with swivel cap, we tackle the tri-point screws, which seem to be attracted by three magnets that handle docking to the wireless charging stand.
- Expecting a booby trap, we're surprised by the long ribbon cable connecting the heart rate sensor to the internals. The blue rubber seal around the Galaxy's edge might need replacing before reassembly, if damaged, but there's no glue so far. We also spot rubber gaskets for the mic, ambient light sensor, and pressure sensor.
- After disconnecting the display, this nucleus separates into a few smaller elements. There is still no sign of glue. The display's flex cable carries the ambient light sensor, which peeps through a small hole in the display. The display on our 46mm version has a diameter of 33mm.
- The computational center looks like a bug's head, with two button cables as antennae. There's little else on this side, save for two blocks of resin. Structural integrity comes from a midframe, which also houses the power source.
- We return to the back cover in search of satellite components. Equipped with a halberd spudger, we probe the heart rate sensor and NFC antenna. The four photo cells of the heart rate sensor are gathered around the light source. The last parts to come out are the service port and the loudspeaker, held fast by two Phillips screws, with a rubber gasket for ingress protection.
- Repairability score: 8 out of 10 (10 is the easiest to repair). Display repair is prioritized. No overlapping design of cables, no fragile ZIF connectors. Despite being water-resistant, the opening procedure is straightforward and glueless. The battery only uses mild adhesive, but the motherboard must be removed for access. A lot of components are modular, so can be replaced separately—except for the twin button cables. The glass digitizer and screen are fused together—meaning a full replacement is quick and easy, but glass-only repairs are impractical. ⏻

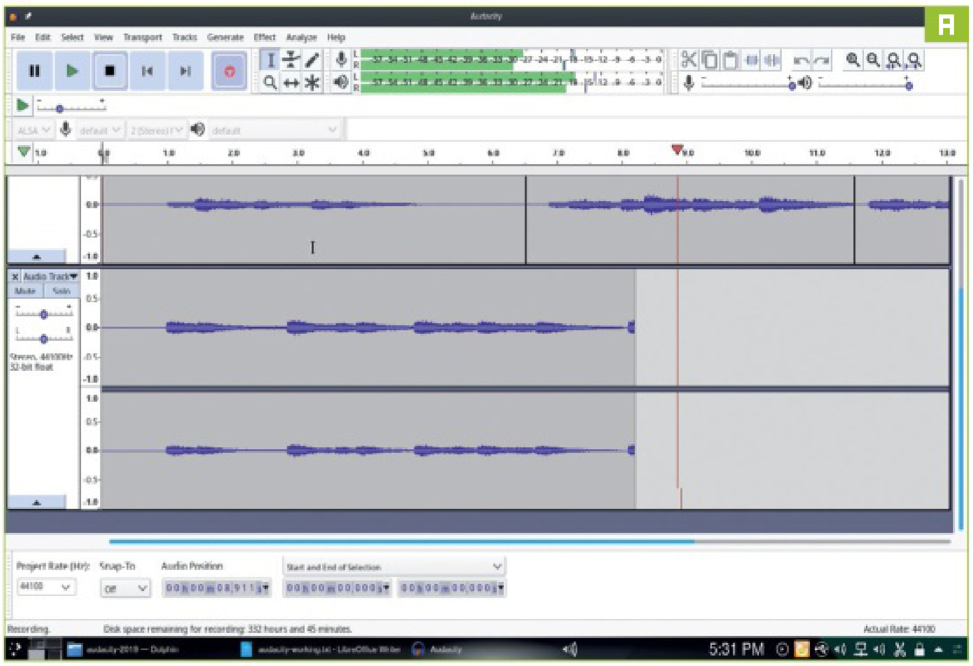
Advanced Audio Recording & Editing

YOU'LL NEED THIS

AUDACITY
Download the open-source software from www.audacityteam.org.

BIG AUDIO SUITES ARE GREAT, but they can be intimidating to say the least—sometimes you just want something that works, without having to think too much about it. Enter Audacity, from www.audacityteam.org.

Audacity has become popular on all desktop platforms, and has started popping up on YouTube tutorials quite a bit. Known for its ease of use and intuitive interface, Audacity is perhaps the audio equivalent of Microsoft Paint *[erm… –Ed]*—it can't do deeply complicated tasks, but then it was never intended to do so. It's designed around simple controls that most people can guess their way around, although that doesn't mean you can't achieve some great results with it. –**JOHN KNIGHT**



Recording.

Disk space remaining for recording: 332 hours and 45 minutes.

1 AUDACIOUS AUDIO

Although, technically, Audacity can record multi-channel digital audio, the interface really isn't designed for it—it's meant for simple recording in mono or stereo. If you're looking for a Pro Tools replacement, Audacity isn't it; try Ardour instead. However, if you're looking for an easy-to-use wave editor and a fast, simple way of making stereo mixes, Audacity may be what you're looking for. This open-source tool enables you to get deep into the waveform and perform easy cuts and edits, making it very popular among technicians who want to cut together quick edits, and apply basic effects without getting bogged down by a complex interface.

» Nevertheless, Audacity has undergone some changes lately, and at first glance, some long-time users might have their nose put out of joint [**Image A**]. So, for the new users, we'll give you a walkthrough of the major features, and for the veterans, we'll show you what's changed, and how to adapt to it. We won't be showing you all the features, but we will cover enough of the essentials to start a workflow.

2 SOUNDS GOOD

In order to show you how Audacity works, we first need to have some audio to play with. You can either import some existing audio, or just record random sound (blank silence is fine)—it doesn't really matter, as long as there's an audio track of some sort. If you want to add some existing audio tracks, you can run through a maze of GUI prompts if you really like, or you can just click and drag them on to the editing field. As for recording audio, just hit the "Record" button in the main toolbar, and if you're using an Internet mic, clap your hands a few times—that should show up on the waveform. Press "Stop" when you're done, and we'll be able to look at Audacity properly.

» The Device Toolbar enables you to change which soundcard you want to use, and which audio host will run the system—likely your motherboards HD audio output (generally Realtek). For your recording device, you probably have options for Default (again through your motherboards integrated audio) or for a USB microphone if present. A dedicated soundcard will probably run quicker and be kinder on the system.

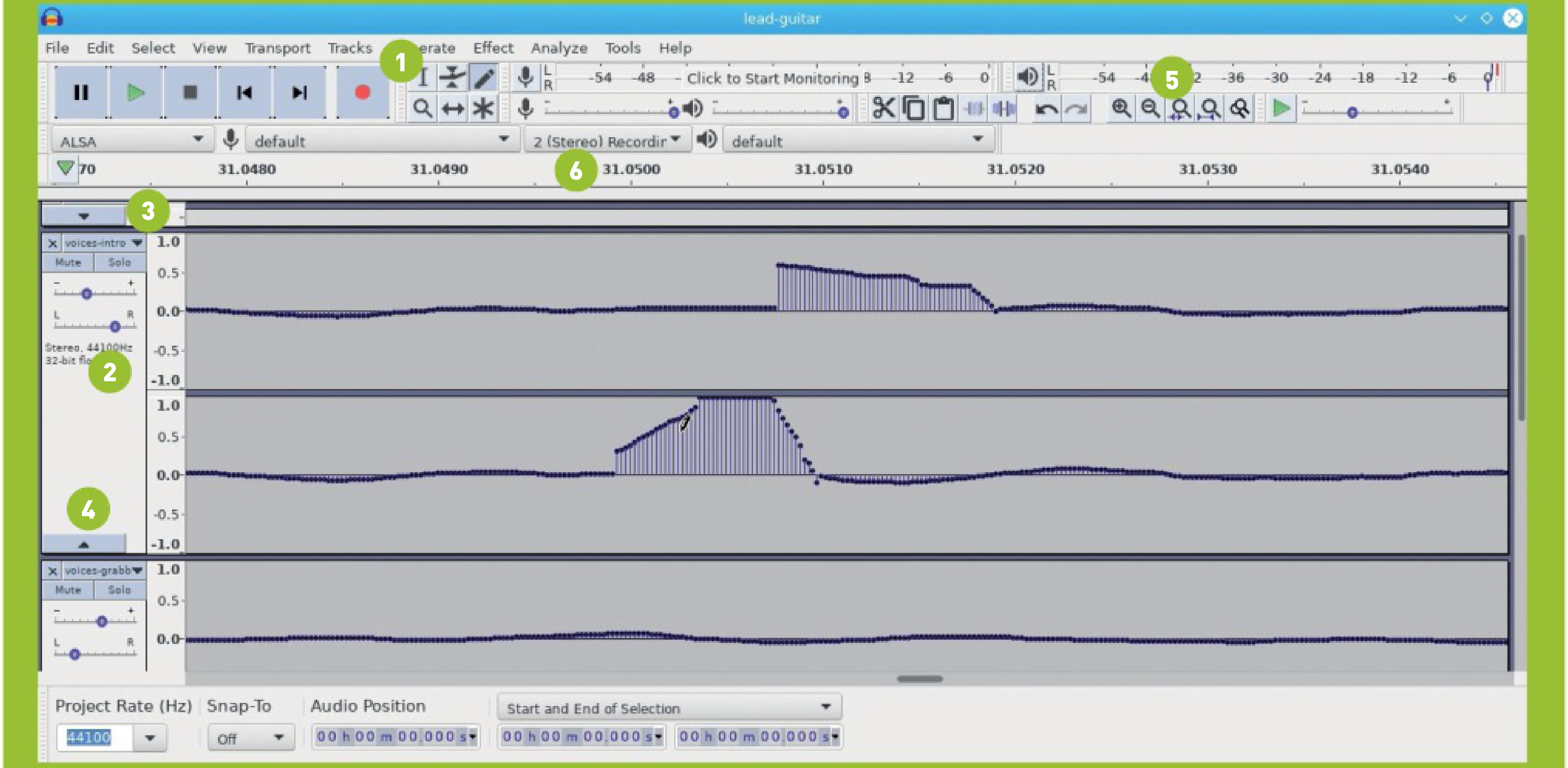
» Perhaps of chief importance is the number of Recording Channels. Here you can choose between one channel for mono or two for stereo. Don't just choose stereo because you think stereo equals better. If you're recording a single instrument, it may be easier in the long run to record this in mono, even if you will ultimately be creating something in a stereo image. If you're recording something like an FM broadcast or capturing computer audio, this is something you will want to do in stereo.

3 TOOLS TOUR

Audacity's toolbar—which has the snappy name of "Audacity Tools Toolbar"—houses the main tools, such as Select, Draw, Time Shift, and Zoom. By default, the Selection tool is enabled, and is used for highlighting audio before doing things such as cutting and pasting, muting sections, and so on. Cutting and pasting is done by the usual shortcuts, so you'll have no problems there, and you can use the Delete key on selected bits of audio. You can select the magnifying glass for Zoom: Left-clicking zooms in, and right-clicking zooms out. You can zoom right down to the grains of each waveform if you want to do some hardcore manual editing, and if you select the Draw tool, you can even re-draw the shape of the wave.

» If one of your tracks is out of sync with the other recorded tracks, you can use the Time Shift tool to correct it. If you click and drag left or right it moves the timing forward or backward, and you can even move a track to before the zero-second mark. Further on the

INTRODUCING THE INTERFACE


lead-guitar
File Edit Select View Transport Tracks Generate Effect Analyze Tools Help
Click to Start Monitoring
ALSA
default
2 (Stereo) Recording
default
31.0480 31.0490 31.0500 31.0510 31.0520 31.0530 31.0540
voices-intro
Mute Solo
Stereo, 44100Hz 32-bit float
voices-grabb
1.0 0.5 0.0 -0.5 -1.0
Project Rate (Hz) Snap-To Audio Position Start and End of Selection
44100 Off
00 h 00 m 00.000 s
1
2
3
4
5
6

1. MAIN TOOLBAR
Where your primary tools are kept, such as Selection, Time Shift, Zoom, and Envelope.

2. TRACK CONTROLS
Tools for muting, soloing tracks, and changing the gain and the pan. This is where you can really shape your soundscape.

3. TRACK MENU
Provides a bundle of more advanced controls, such as mono-to-stereo conversion, as well as renaming and moving tracks.

4. COLLAPSE BUTTON
This squishes up any track into a kind of sliver, which then can be expanded later.

5. ZOOM CONTROLS
Dedicated buttons for specific zoom functions, including zooming in to a selected portion of a wave, or zooming out 100 percent.

6. RECORDING OPTIONS
Choose which audio system to use, which device to record from, mono or stereo, and change the playback device.

right are the zoom controls, all with different magnifying glass icons, which replicate the Zoom tool. The icons with the "+" and "-" enable you to zoom all the way in to the fine points of a waveform, or back out so you can see the track as a whole.

›› Less obvious, but crucial when you get the hang of things, are the next two controls: "Fit selection in window" and "Fit project in window." When you have some audio selected, "Fit selection in window" zooms in until your highlighted selection fits perfectly on the screen—no more and no less. When you need to see the project as a whole again, "Fit project in window" zooms all the way back out in one click.

4 GOING SOLO

Moving to the tracks in the main editing field, track controls are on the left. Each track has a close button, which removes the track, and a drop-down menu. Plenty of advanced options are in the drop-down menu, but the main controls you'll use are the "Mute" and "Solo" buttons, plus the two sliders. The "Mute" and "Solo" buttons should be fairly self-explanatory, but remember that you mute each track individually, rather than all of them en masse. While the "Solo" button obviously mutes all other tracks, you can "solo" more than one track—something that will annoy many pedants.

›› Moving down to the two sliders, the first is the "Gain" control. In simple terms, it basically turns up and down the volume of each track; in audiophile terms, this is where pre-amp adjustments happen. The second slider is "Pan" control, which lets you move sound left and right in a stereo image.

›› Looking to the advanced controls in the drop-down menu, the first option is "Name," where you can rename each track individually. The "Move Track Up" and "Move Track Down" features become essential when you start doing elaborate multi-layered editing, as they let you re-order the tracks. More advanced users will want to check out the "Swap Stereo Channels," "Split Stereo Track," and "Split Stereo to Mono" options. These features are so much quicker and easier than those you encounter on pro editing suites, and are perfect for anything that involves switching between mono and stereo.

5 GET RECORDING

Getting started with the first track is the hardest part of any recording session. You've got to make sure the correct input is selected, get the levels right, and check that your recording is actually coming through on your program's waveform. If you're very lucky, you'll be able to just hit "Record," and it will work. But even with something as easy as Audacity, you'll probably be greeted with a blank wave, and need to spend 10 minutes switching between inputs to find what's wrong.

›› Before we get too negative, try your luck, and hit the big "Record" button. Make some noise, and if all is well,

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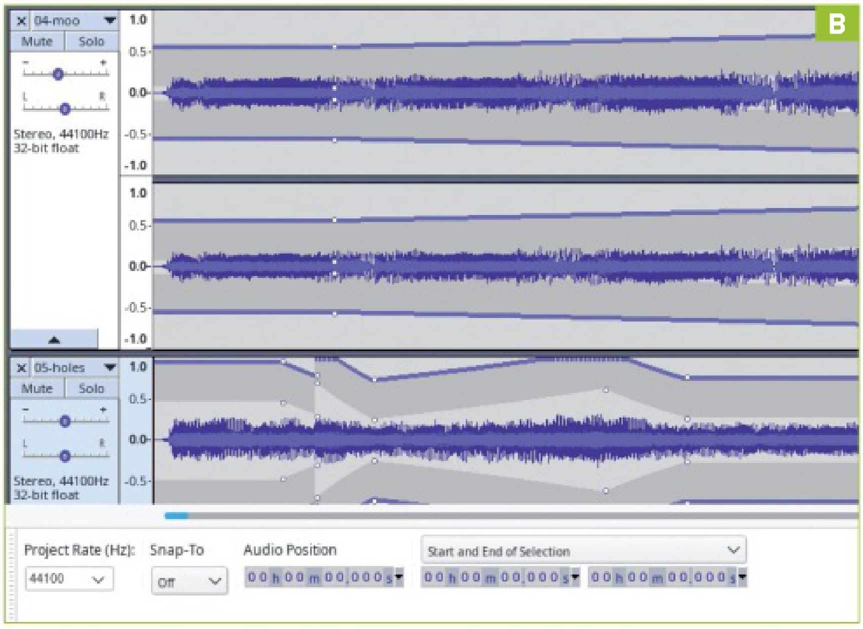


Project Rate (Hz): 44100
Snap-To: Off
Audio Position: 00 h 00 m 00.000 s
Start and End of Selection: 00 h 00 m 00.000 s 00 h 00 m 00.000 s

you will see the sound outputting into a waveform. If you were greeted with silence and a flat line, first make sure the recording option for that channel is enabled in your mixer, and that it's not muted. Otherwise, try changing entries from the "Recording Device" drop-down.

» Unless you have a Goliath of a soundcard, there shouldn't be too many entries to test, and you can probably choose between several channels under "Default." Again this will probably default to your motherboards integrated audio, so be prepared to dive into your soundcard's settings. You may have to open the "Advanced" tab in the "Audio Volume" section, and from the "Profile" drop-down box, we used "Analog Stereo Duplex." If you're using digital speakers, just try anything that enables an analog input. Once you have something that works, write down what you did, and don't mess with it—record everything you can while it's working. After this, Audacity should be smooth sailing. Now to tweak the recording levels.

» The smaller the wave in height, the worse the signal-to-noise ratio is, making the track hissy and probably muffled. The louder the recorded input, the more likely it will "clip" the edge of the waveform, and sound horrible and distorted. You want to strike a balance where a good amount of space in the waveform is used, but also leave room in the dynamic range for sudden loud notes, such as a big cymbal crash. Keep turning up your instrument, input, or mixer desk until your waveform is getting near the edge, and back it off if it starts clipping. Depending on your underlying audio system, you may be able to turn the recording levels back down with the slider at the top-right of the window.

6 RUNNING TRACKS

Recording a piece of audio is great, but you can do that on just about anything. What makes Audacity so popular is that it does multi-track layered recording, and probably makes it easier than any other program out there. If you're new to the concept of multi-track recording, it enables you to record sounds one at a time in layers, slowly building up a soundscape.

» For instance, the most common usage is in music, where you may record each musician in isolation, rather than recording the band as a whole. You might lay down a drum track first, and with that first drum track in their headphones, the bassist can record their track in a new second layer. Then the guitarist could hear the drums and bass playing through their headphones, and record their guitar in a third layer. With the instrumentals finished, the singer can record their vocals.

» If you're a seasoned Audacity user, you need to know that things have changed. When you hit the "Record" button, Audacity used to create a new track automatically, and start recording in that. Now when you click "Record," Audacity starts recording on the end of the current track, and just keeps on adding to it.

» If you would rather record into a new track, use the keyboard instead of the mouse. Pressing R records on to the end of the current track, but Shift-R records into a new track. If you're determined to have things the way they used to be, you can change it by choosing "Edit → Preferences" from the main menu. Open the "Recording" section, and in the "Options" field, click "Always record on a new track."

» Note that Audacity now has latency correction built in, but some audio device settings may result in an error regarding latency timing. If this is the case, you can also tweak your latency correction settings in the "Preferences" window. In the "Devices" section, you can tweak the buffer length and "Track shift after record" settings in the "Latency" field.

7 TRACK-ON-TRACK ACTION

Not only can Audacity do multi-track recording, but you can also edit each recorded layer individually, making tweaks to any layer without upsetting the others. Going back to the band example, if you simply recorded them in one live image, you would have to mix them together as a whole, and you wouldn't be able to make many adjustments. But with separate tracks, you can correct mistakes, and tweak each recording individually.

» For instance, if the guitarist plays a bum note or the drummer coughs during silence, you can simply mute their second of bad audio, and the rest of the song is unaffected. Or, if one instrument is too loud, you can turn the volume down on just that track, without affecting the volume levels of any other musician.

» If you want to turn a track up or down, just move that track's "Gain" slider. If you wish to mute a second of audio, simply highlight the portion of audio you don't want, and press Ctrl-L, or click "Edit → Remove Special → Silence Audio." For more advanced users who want to do volume automation, there is the Envelope Tool in the

ADDING EFFECTS

Because Audacity cuts out the complex audio buses that underlie big editing suites, adding effects is incredibly easy. Just select whatever audio you want to apply an effect to, and choose it from the "Effect" menu—and if more input is required, most effects have a settings window with a handy "Preview" button. As for the effects included by default, you will want to pay particular attention to Fade In and Fade Out, Amplify, and Equalization. Note that Amplify is useful for making things both louder and quieter, because you can simply enter a negative value if you want to turn something down.

While Audacity has a number of effects pre-installed, we recommend installing extra plugins. Audacity supports LADSPA, LV2, Nyquist, VAMP, and VST plugins, and if you use Linux, you should be able to find quite a few in your package manager. Just browse around and install anything you like the look of. Anything to do with reverb, chorus, or flange is probably a good idea.

main toolbar [**Image B**]. This enables you to make smooth volume transitions by creating two lines: one on the edge of the track and one on the edge of the waveform, which can be dragged around to reshape the wave's amplitude. The outer line brings down volume overall, but the inner line can be dragged upward to increase the wave's amplitude.

8

PAN-DEMONIUM

The really fun bit of Audacity is creating custom stereo images. You can take a large selection of tracks, and by sliding the "Pan" control on each, you can create a large stereo image in your own virtual soundscape, making your music or home movies really come alive.

›› If this is something you'll do a lot of, a common technique is to record individual voices or instruments separately in mono. This makes it easier to manage when you want to create a stereo mix, because if the imported track is already in stereo, it adds unnecessary complexity and file size. If you've recorded each voice in mono, simply import all the tracks into the same session, and assign their place in the stereo mix with the "Pan" slider.

›› A common scenario is with digitally recorded drums, where each drum mic has recorded to a separate channel, with each channel outputting to a separate wave file. If you import all of these files at once, you just hear a dull mono image, but if you use the "Pan" slider, you can place each drum and cymbal virtually, based on where they would sit in real life.

›› For instance, overhead mics are usually mixed far-left and far-right, the hi-hat on the left, the ride cymbal on the right, and the kick and snare are usually mixed around the center. If you put the snare slightly left and the kick slightly right, you will be able to hear each drum more clearly in the mix, and avoid overlapping frequencies.

9

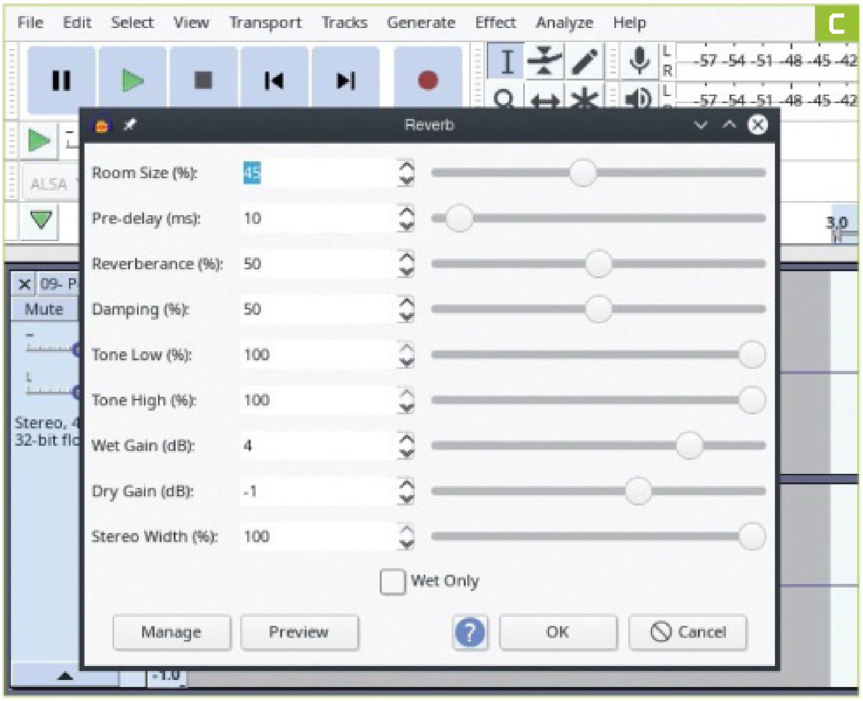
TRADE-FREE EXPORTS

Simply saving your work isn't going to be of much use, because the only thing that can read Audacity files is Audacity—you need to export your work. If you click "File" and look at the "Export" sub-menu, you'll see a number of options. First, we need to differentiate between "Export as…" and "Export Selected Audio." The "Export Selected Audio" option is simple enough: Whatever you highlight with the Selection Tool is saved to an external audio file. The "Export as…" and "Export Audio" options save an image of your work exactly as it sits now—mixer settings, effects, and everything. This is something you'll want to do when you've got everything just the way you want it.

›› WAV files are something of a de facto standard in the mixing world, because pretty much anything can read them, although no one's going to shout at you for using FLAC files. Use WAV or FLAC wherever you can while you're mixing—most compressed formats, such as MP3 or OGG, are lossy, and should only be used for distribution after you've already made a proper master. If you don't like WAV, OGG, or MP3, more encoding options are available using the "Export Audio" function.

›› For Audacity veterans, there is some cool new time-saving functionality for the "Tracks" menu, under the "Mix" sub-menu. There are three options: "Mix Stereo Down to Mono," "Mix and Render," and "Mix and Render to New Track." The first option is pretty self-explanatory, converting any selected stereo tracks into mono. "Mix and Render" converts all your current tracks into one single track, including any volume or pan adjustments, added effects, and so on. Note that you have to "Select All" to make this work properly.

›› Lastly, "Mix and Render to New Track" does the same as "Mix and Render," except it leaves the existing tracks as they are, and creates a new rendered track beneath your current tracks.



C

Room Size (%): 45

Pre-delay (ms): 10

Reverberance (%): 50

Damping (%): 50

Tone Low (%): 100

Tone High (%): 100

Wet Gain (dB): 4

Dry Gain (dB): -1

Stereo Width (%): 100

☐ Wet Only

10

ALL MIXED UP

Audacity has undergone quite a few changes of late, most of which push it toward being a more viable and professional multi-track recording program. However, these changes also add to its bulk and complexity; the simple truth is that Audacity is no longer as simple as it once was, which may scare off some new users, and even put off some veterans.

›› Nevertheless, Audacity is still the friendly and intuitive program it has always been [**Image C**]. As long as it doesn't gain much more in complexity, existing users should be able to adjust, and Audacity will maintain its niche as the easiest way to get into multi-track recording and editing. ⏻

USING JACK

Running Audacity with JACK rather defeats the purpose of its simple interface, but maybe there's some kind of effect chain you want to create, or some kind of MIDI program you need to use, and the only way to do it is JACK. First, you need to make sure JACK runs properly. We recommend installing QjackCtl, which provides a straightforward GUI for starting and configuring JACK.

If you try to start JACK and get an error, first try specifying your soundcard by clicking "Setup," and in the "Settings" tab will be the "Interface" drop-down menu. Change the setting from "(default)" to your soundcard's actual device name. If this doesn't work, make sure "Driver" is set to "alsa" instead of "dummy," and if it still doesn't work, try disabling "Realtime."

To change Audacity from using ALSA to using JACK, open your system settings by choosing "Edit → Preferences," and in the "Devices" tab will be the "Interface" section. For "Host," open the drop-down menu, and change the entry from "ALSA" to "JACK Audio Connection Kit."

It's best to leave everything at default settings and see if you can record as-is. If you need more JACK connectivity, you can change Audacity's "Playback" and "Recording" devices to JACK, though you may need to manually connect ports in QjackCtl's "Connect" window. JACK is messy and temperamental at the best of times. Don't use it with Audacity unless you really need to.

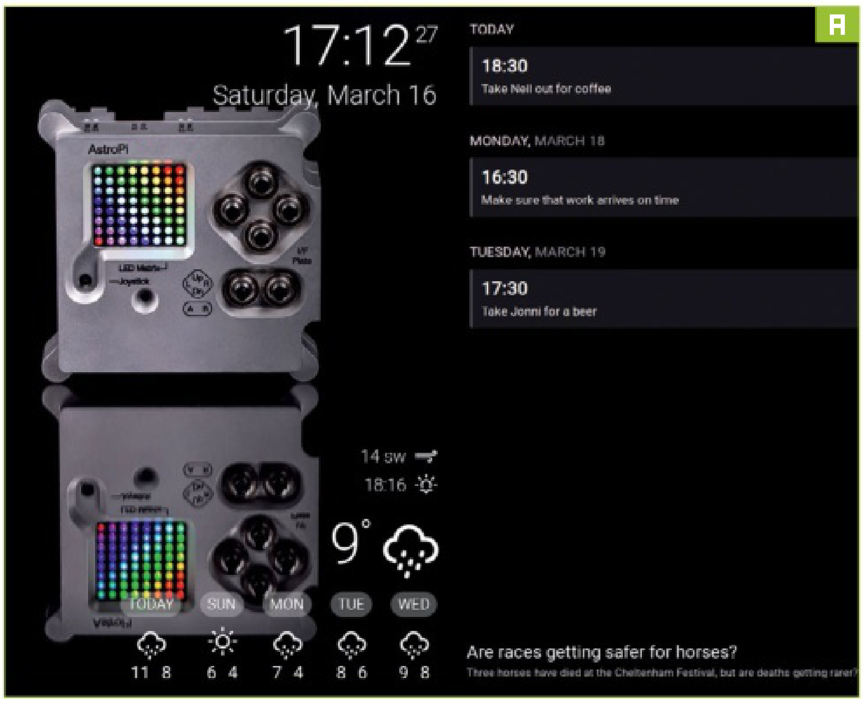
Create an Information Radiator in DAKboard

YOU'LL NEED THIS

RASPBERRY PI
With the latest copy of Raspbian Lite and an Internet connection.

THE TERM "INFORMATION RADIATOR" is a typically obscure tech way of saying "device that displays information on a screen." This information can range from simple newsfeeds and advertisements to complex service statuses. They are typically used in hotel lobbies to display news, weather, and ads, and in tech offices, where developers need to see the status of their work at a glance.

In this project, we're going to make our own simple information radiator using DAKboard and a Raspberry Pi. The best type of Pi for this project is any of the Pi 3 models or a Pi Zero W, because they all come with built in Wi-Fi connectivity—but if you have an older model, you can easily add your own Wi-Fi dongle. –LES POUNDER



TODAY

18:30
Take Neil out for coffee

MONDAY, MARCH 18

16:30
Make sure that work arrives on time

TUESDAY, MARCH 19

17:30
Take Jonni for a beer

Are races getting safer for horses?
Three horses have died at the Cheltenham Festival, but are deaths getting rarer?

1 SET UP YOUR SCREEN

DAKboard is a customizable display—available as a physical device, or just as a service—that can show photos, RSS feeds, weather, and calendars [**Image A**]. To start using DAKboard, sign up for a free account at https://dakboard.com, then log in. The first screen we encounter is called "Screens," and here we can manage a number of them. For this tutorial, we'll edit "My Predefined Screen," so click it to start editing.

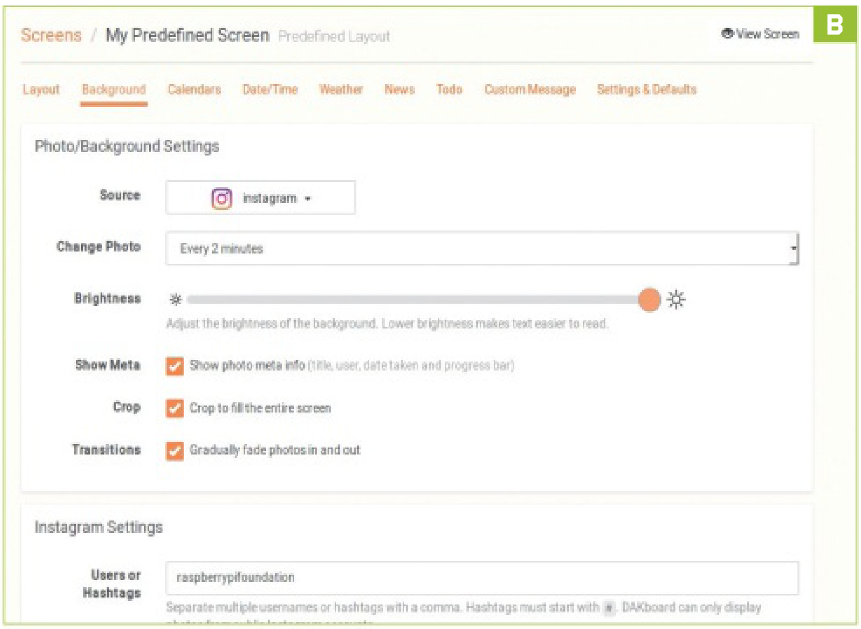
›› The first task is to set the layout of the screen, so try out a few options. Simply click an option and then "Save Changes." In the top-right of the screen is "View Screen"—open this in a new tab and it displays your screen. There should be a large image on the left and a black space on the right. In the bottom-left is the weather. All of these options will be edited later; for now, just change the layout to "Big Calendar." The next step is to alter the background image, so click "Background," and in the new screen click "Source" to choose the source of your images. We're going to use Instagram as the image source [**Image B**], specifically images from the Raspberry Pi Foundation. In "Instagram Settings," add the user `raspberrypifoundation` and click "Save Changes." Now go back to the tab we opened earlier, and click refresh to see images from the Raspberry Pi Foundation's Instagram feed.

›› Moving on, we can set up our calendar. In this example, it is the Magazine Family Calendar, reminding the team when to make the tea, drink beer, and do work *[not in that order, though—Ed]*. First, we enable the calendar and set it to show seven days' worth of content at once. In the "Calendars" section, we provide an iCal URL, which in this case is from a Google Calendar we set up for this tutorial.

2 CREATE A CALENDAR

To get the iCal URL for a Google Calendar, open Google Calendar, and then click the three dots next to the calendar. Click "Settings and Sharing," scroll down to "Access Permissions," and click "Make this calendar public." Now scroll down to "Public Address in iCal format," and copy the URL below it. Paste this URL into the "Calendars" section in DAKboard, and give the calendar an appropriate name. Click on "Save Changes," then go back to the other tab, and refresh to see the calendar appear.

›› In the next section, we can alter the time and date according to where we are in the world—this is pretty self-explanatory. Next, we configure the "Weather" tab, where can set the source of our weather data to one of three providers. For this tutorial, we'll set it to OpenWeatherMap, and then set the location to where we live—DAKboard helps you find the nearest location. We set the units to those required—Fahrenheit or Celsius. We lastly set the extended forecast to five



Photo/Background Settings

Source: instagram
Change Photo: Every 2 minutes
Brightness
Adjust the brightness of the background. Lower brightness makes text easier to read.
Show Meta: ☑ Show photo meta info (title, user, date taken and progress bar)
Crop: ☑ Crop to fill the entire screen
Transitions: ☑ Gradually fade photos in and out

Instagram Settings

Users or Hashtags: raspberrypifoundation
Separate multiple usernames or hashtags with a comma. Hashtags must start with #. DAKboard can only display

SHARE THE SCREEN

You can check how your screen looks by clicking "View Screen" at the top-right of the DAKboard interface. The only way to share this screen with the Pi is to use the "Private URL" that is in the "Settings & Defaults" menu. Remember: Do not share this URL with others, because it contains your private information!

days. Click "Save Changes," and then go back to the screen tab, and click refresh to see the results.

3 FEED ME

The next step is to add a newsfeed to the screen, and for this we go into "News," and enable "RSS." In the "News Feed URL," we paste the "Top Stories" newsfeed from CNN, which can be found at rss.cnn.com/ress/edition.rss—but feel free to use any RSS feed you want. Click "Save Changes," and then go back to the other tab, refresh, and watch as the news is displayed in the bottom-right of the screen [**Image C**].

» In the next section, we can set up a to-do list; for this, we've used our Todoist account, which was easily linked to DAKboard via a short wizard in this section. Then we chose the correct list to show, in this case our to-do list for today. Click "Save Changes," then go back to the other tab, and refresh. You can see the list appear at the left of the screen, just under the time and date.

» With all of the configuration complete, go to "Settings & Defaults," give the screen a name, and click "Save Changes." Now write down the "Private URL" link, because we will need this later. Also, do keep this link private....

4 PI LITE

Our Raspberry Pi needs the latest Raspbian Lite release. This gives us the bare operating system and a web browser, ideal for our needs. We also need an Internet connection in order to load the DAKboard screen. On the Raspberry Pi, we open a terminal, and edit a file that enables the web browser to automatically open when the operating system starts. In the terminal, type the following command, and press Return.

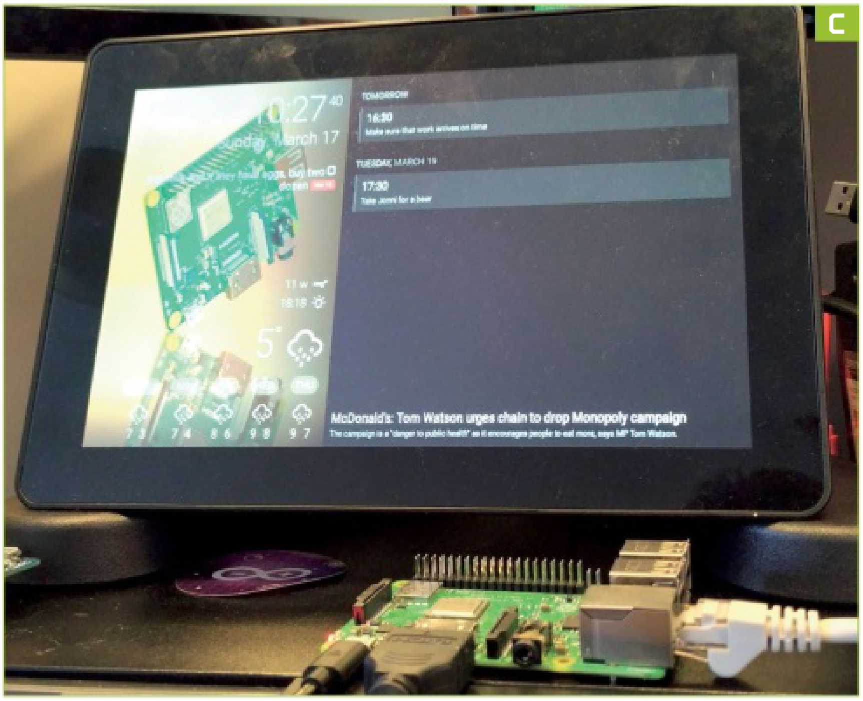
```
$ sudo nano /etc/xdg/autostart/RPI-MPC.desktop
```

» We are going to create a config file that creates a desktop entry for an application. This opens the Chromium browser when the desktop loads, sets the window size to 1920x1080, and specifies full-screen kiosk mode to prevent anyone exiting the application. It also suppresses error messages and runs in incognito mode. Remember your DAKboard private URL from before? Replace `PRIVATE URL FROM DAKBOARD` with that address in the following:

```
[Desktop Entry]
Type=Application
Name=RPi-MPC
Comment=Information Radiator
NoDisplay=false
Exec=chromium-browser PRIVATE URL FROM DAKBOARD
--window-size=1920,1080 --start-fullscreen
--kiosk --incognito --noerrdialogs --disable-translate --no-
first-run --fast --fast-start --disable-infobars --disable-
features=TranslateUI --disk-cache-dir=/dev/null
NotShowIn=GNOME;KDE;XFCE;
```

» If you want to know more about what these command-line arguments do, especially in the `Exec=` line, have a look at the Raspbian Lite documentation—there are some very handy commands in there.

© DAKBOARD/RASPBERRY PI FOUNDATION


C
0:27 40
Sunday, March 17
TOMORROW
16:30
Make sure that work arrives on time
TUESDAY, MARCH 19
17:30
Take Jonni for a beer
5°
McDonald's: Tom Watson urges chain to drop Monopoly campaign
The campaign is a "danger to public health" as it encourages people to eat more, says MP Tom Watson.

5 READY TO GO

To save, press Ctrl-O, then press Return, then Ctrl-X to exit. Still in the terminal, our next step is to edit a file that will prevent the display from blanking after five minutes. In the terminal, type:

```
$ sudo nano /etc/lightdm/lightdm.conf
```

In the file, look for the line:

```
#server-command=X
```

Change it to:

```
server-command=X -s 0 dpms
```

» To save, press Ctrl-O, then press Return, then Ctrl-X to exit. Now reboot the Pi, and once it has successfully rebooted to the desktop, it will automatically load our DAKboard screen.

» There you have it: our own information radiator for the home, office, and data center. ⏻

ROTATING THE DISPLAY

Your information radiator will most likely be in landscape orientation, just like the monitor on your desk. But what if you want to show off your DAKboard using a portrait display? Well, rotating the screen is quite simple—perhaps not as simple as on Ubuntu/Fedora desktops, but all it requires is a little basic terminal work. In Raspbian, open a terminal and type:

```
$ sudo nano /boot/config.txt
```

Scroll to the bottom of the file, and add the following two lines:

```
#ROTATE HDMI
display_hdmi_rotate=X
```

Change the `X` to `1` for 90 degrees, `2` for 180, or `3` for 270 degrees. To save, press Ctrl-O, then press Return, then Ctrl-X to exit.

Reboot the Raspberry Pi and your display should now be rotated and ready for use. If the effect is not as desired, change the value of `X` to another number between 0 and 3. To turn off the rotation, just add a `#` to the start of the line, and the system will ignore it.

Childproof Your Windows 10 PC

YOU'LL NEED THIS

WINDOWS 10
With a Microsoft account for both you and your child.

BEING A PARENT IS STRESSFUL AND TIME-CONSUMING ENOUGH, without having to worry about what your child is using their (or your) PC for, or for how long. To save you from having to constantly monitor their use in person, Windows 10 includes a powerful collection of parental control options, which can act as your eyes and ears when you are busy with other things.

Using built-in parental controls, it's possible to place restrictions on the websites that can be visited, the apps that can be run, and when the PC can be used. While you might expect the options to be configured in "Settings," you need to visit your Microsoft account online, and from there manage all the user accounts you have set up on your PC and added to your family. This enables you to control settings from any Internet-connected device, and monitor your child's PC use remotely. –**MARK WYCIŚLIK-WILSON**

1

SET UP CHILD ACCOUNTS

To take parental control of a child's account, it first needs to be configured correctly. To do that, go to "Start → Settings → Accounts → Family & other users." Click "Add a family member," and create as many accounts as you need for the members of your family—just follow the on-screen instructions, indicating that you would like to create an account for a child [**Image A**].

2

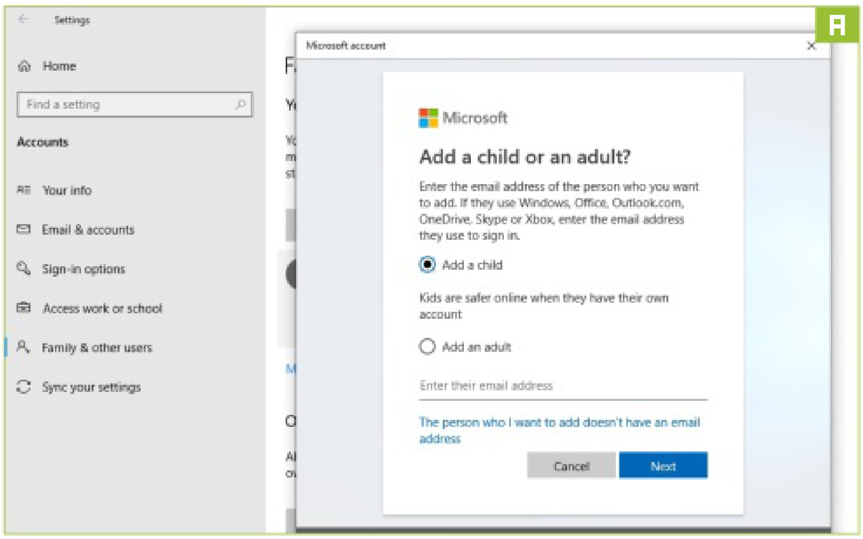
ENSURE ACCOUNTS ARE LIMITED

If you're setting up a child account from scratch, it will be as a Standard User, so the account can't be used to make potentially damaging changes to Windows. However, if you're using an existing account, you need to check its status. In the "Family & other users" window, ensure none of the accounts are set as Administrators. If any are, click them, then "Change account type," and select "Standard User" [**Image B**].

3

ADJUST FAMILY SETTINGS

While we refer to "parental controls," Microsoft prefers to use the phrase "family settings." Any restrictions you wish to place on the user accounts you have created need to be put in place through the "Family" section of your Microsoft account. To access this, just click the "Manage family settings online" link on the "Family & other users" page of "Settings" [**Image C**].


A
Settings
Home
Find a setting
Accounts
Your info
Email & accounts
Sign-in options
Access work or school
Family & other users
Sync your settings
Microsoft account
Microsoft
Cancel
Next

Add a child or an adult?

Enter the email address of the person who you want to add. If they use Windows, Office, Outlook.com, OneDrive, Skype or Xbox, enter the email address they use to sign in.

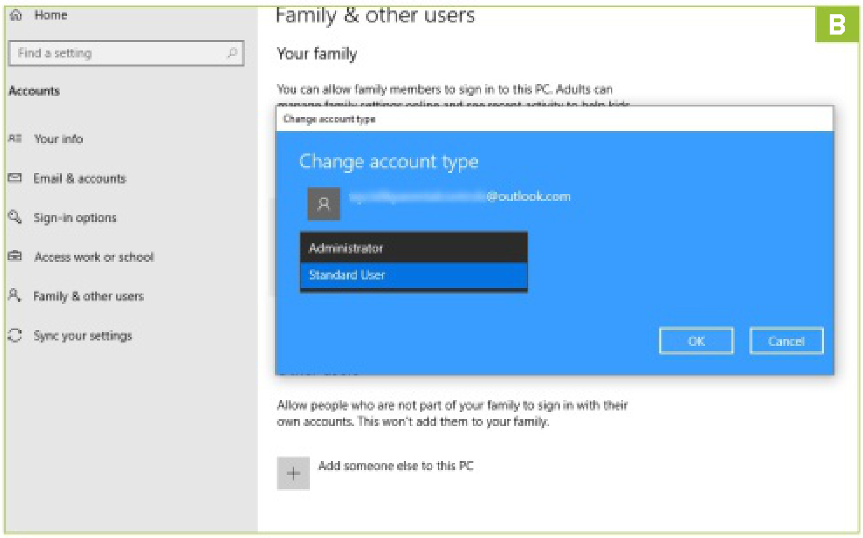
● Add a child

Kids are safer online when they have their own account

○ Add an adult

Enter their email address

The person who I want to add doesn't have an email address


B
Home
Find a setting
Accounts
Your info
Email & accounts
Sign-in options
Access work or school
Family & other users
Sync your settings
Change account type
Administrator
Standard User
OK
Cancel
Add someone else to this PC

Family & other users

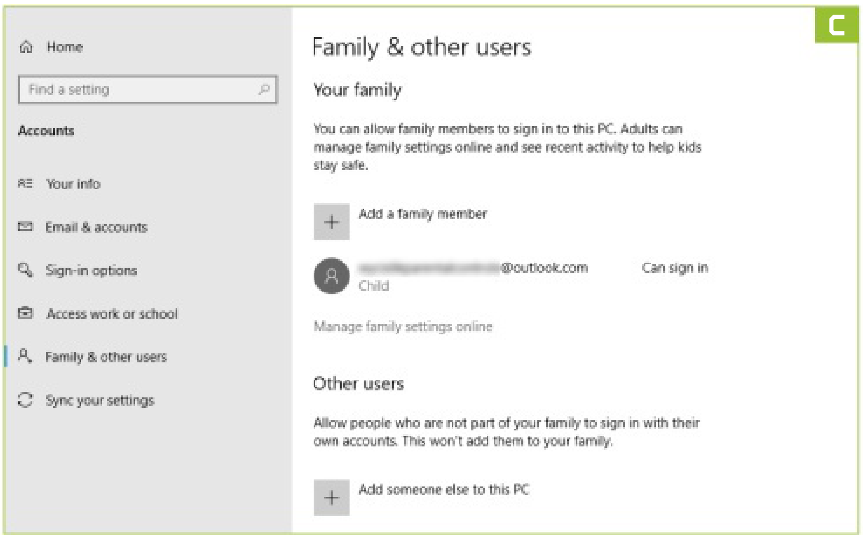
Your family

You can allow family members to sign in to this PC. Adults can

Change account type

[redacted]@outlook.com

Allow people who are not part of your family to sign in with their own accounts. This won't add them to your family.


C
Home
Find a setting
Accounts
Your info
Email & accounts
Sign-in options
Access work or school
Family & other users
Sync your settings
Add a family member
Manage family settings online
Add someone else to this PC

Family & other users

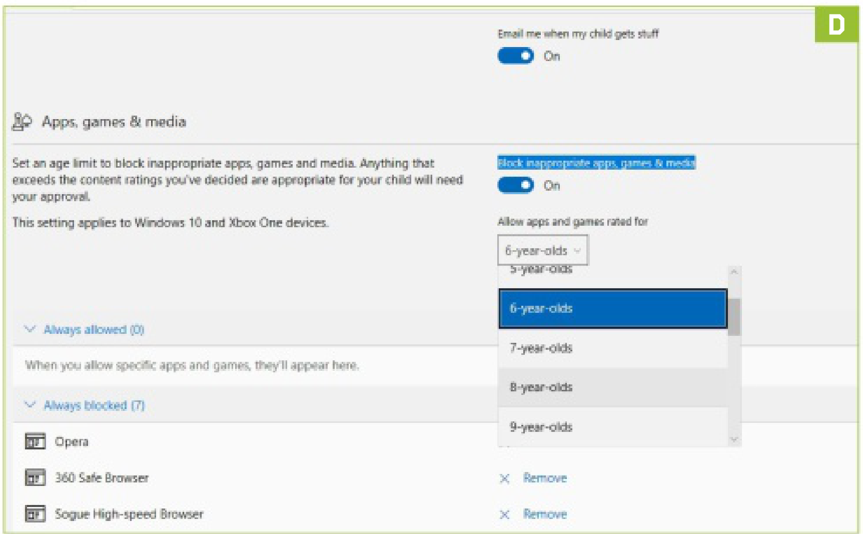
Your family

You can allow family members to sign in to this PC. Adults can manage family settings online and see recent activity to help kids stay safe.

[redacted]@outlook.com Child Can sign in

Other users

Allow people who are not part of your family to sign in with their own accounts. This won't add them to your family.


D
5-year-olds
6-year-olds
7-year-olds
8-year-olds
9-year-olds
Remove
Remove

Email me when my child gets stuff: On

Apps, games & media

Set an age limit to block inappropriate apps, games and media. Anything that exceeds the content ratings you've decided are appropriate for your child will need your approval.

This setting applies to Windows 10 and Xbox One devices.

Block inappropriate apps, games & media: On

Allow apps and games rated for: 6-year-olds

Always allowed (0)

When you allow specific apps and games, they'll appear here.

Always blocked (7)

Opera
360 Safe Browser
Sogue High-speed Browser

4

IMPLEMENT BUYING RESTRICTIONS

When you visit the "Your family" section, you should see a list of any accounts that you've created. Beneath the name of the account you want to impose parental controls on, click "Content restrictions." You can start by using the first two switches to prevent a child buying things through their account without permission, and to send out emails whenever purchases are made.

5

SOFTWARE RESTRICTIONS

Scroll down the page to the "Apps, games, & media" section, and ensure "Block inappropriate apps, games, & media" is enabled. Use the drop-down menu to choose the age rating you are happy for your child to use [**Image D**]. Bear in mind that ratings are somewhat subjective, and you may not necessarily agree that a particular title is suitable for your child.

6

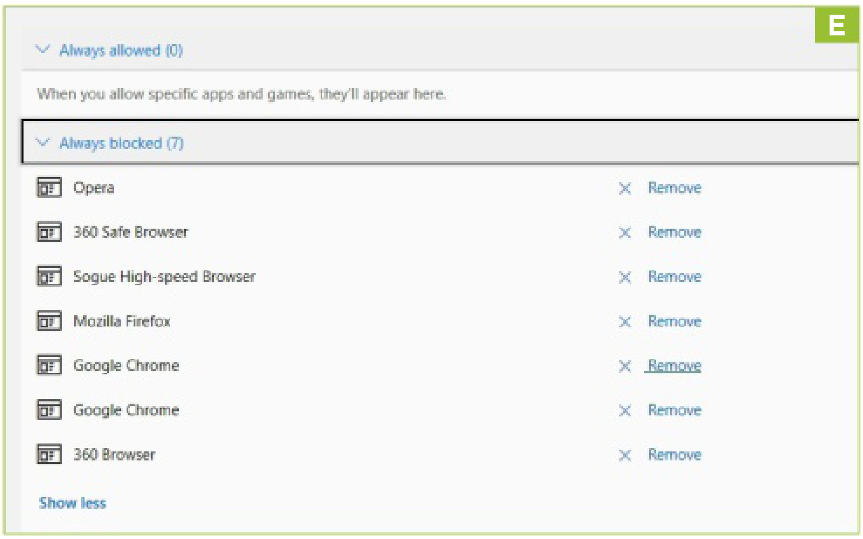
CUSTOMIZE APP RESTRICTIONS

It may be that an app you feel is suitable for your child is blocked by an age restriction—but raising the age limit may not be appropriate. For example, Microsoft blocks some web browsers because they don't offer the same control options as its own Edge, but you can lift these restrictions. In the "Always blocked" list, click "Remove" next to any app you're happy for your child to use [**Image E**].

7

RESTRICT WEB BROWSING

Letting your child have unfettered access to the web can be scary, but you can put limits in place. If there's a site you'd like to stop your child from visiting, enter its URL in the "Always blocked" section, and click the "+" symbol. To ensure the sites you approve of can be accessed, enter their URLs in the "Always allowed" section [**Image F**]. Check the "Only allow these websites" box to limit web access further.



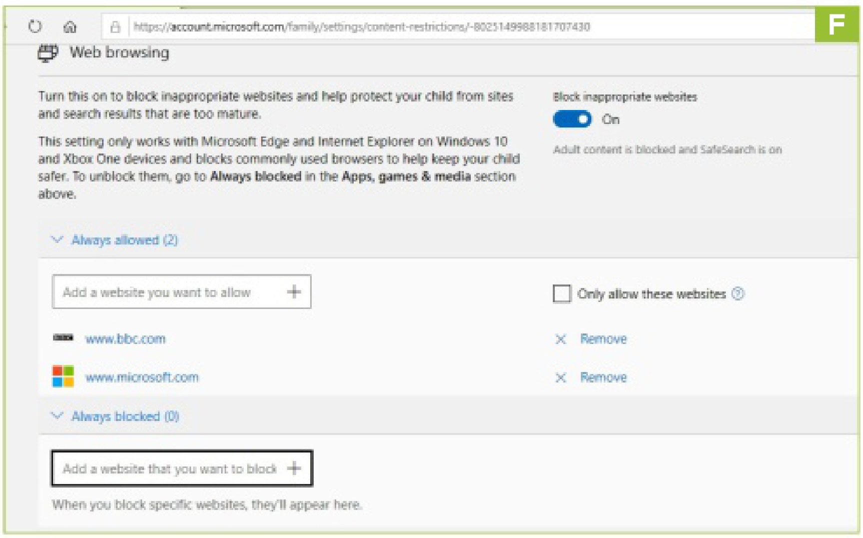
Always allowed (0)

When you allow specific apps and games, they'll appear here.

Always blocked (7)

Opera	× Remove
360 Safe Browser	× Remove
Sogue High-speed Browser	× Remove
Mozilla Firefox	× Remove
Google Chrome	× Remove
Google Chrome	× Remove
360 Browser	× Remove

Show less



https://account.microsoft.com/family/settings/content-restrictions/-8025149988181707430

Web browsing

Turn this on to block inappropriate websites and help protect your child from sites and search results that are too mature.

This setting only works with Microsoft Edge and Internet Explorer on Windows 10 and Xbox One devices and blocks commonly used browsers to help keep your child safer. To unblock them, go to **Always blocked** in the **Apps, games & media** section above.

Block inappropriate websites: On

Adult content is blocked and SafeSearch is on

Always allowed (2)

Add a website you want to allow +

☐ Only allow these websites

www.bbc.com	× Remove
www.microsoft.com	× Remove

Always blocked (0)

Add a website that you want to block +

When you block specific websites, they'll appear here.

© MICROSOFT WINDOWS 10

8

LIMIT COMPUTING TIME

You can place a time limit on how long your child is able to use the computer by scrolling to the top of the page, and clicking the "Screen time" heading. Flick the toggle switches to the "On" position for any computer or console listed that you would like to place limits on, then use the timetable that appears to indicate when screen time should be permitted [**Image G**].

9

LIMIT SPENDING

In Step 4, we mentioned how it's possible to require parental approval before any purchases can be made, but there are more money-related options in the "Spending" section [**Image H**]. Here, you can add some money to your child's account balance, so they can shop online without having to pester you for money at the time of purchase, and without the risk of spending too much.

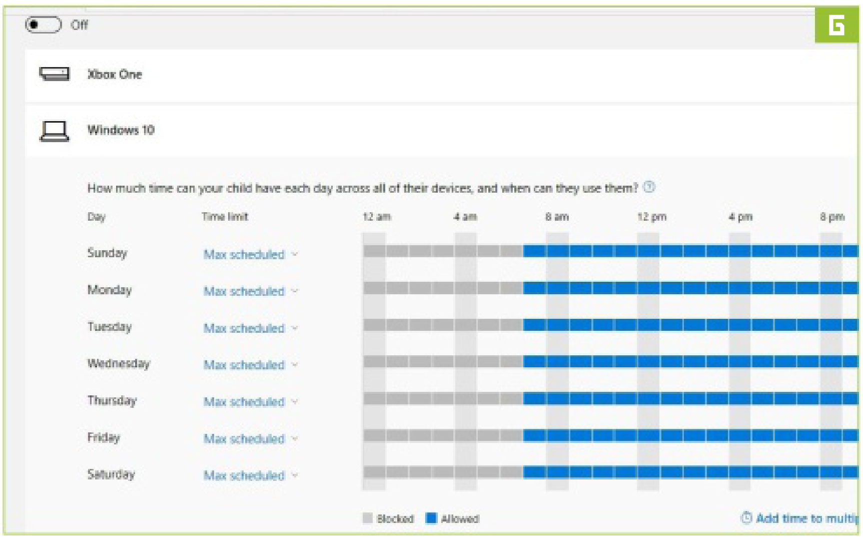
10

MONITOR ACTIVITY

As well as placing restrictions on your child, you can also monitor what they do online and on your PC. Head to "Recent activity" and you will be able to see not only which apps and games they've used, but also the sites they have visited and the searches they've conducted. There are shortcuts to impose restrictions if you see anything that you feel requires action. ⏻

SERVER SUGGESTION

To use parental controls, both you and your child need to sign in to Windows using a Microsoft account.



Off

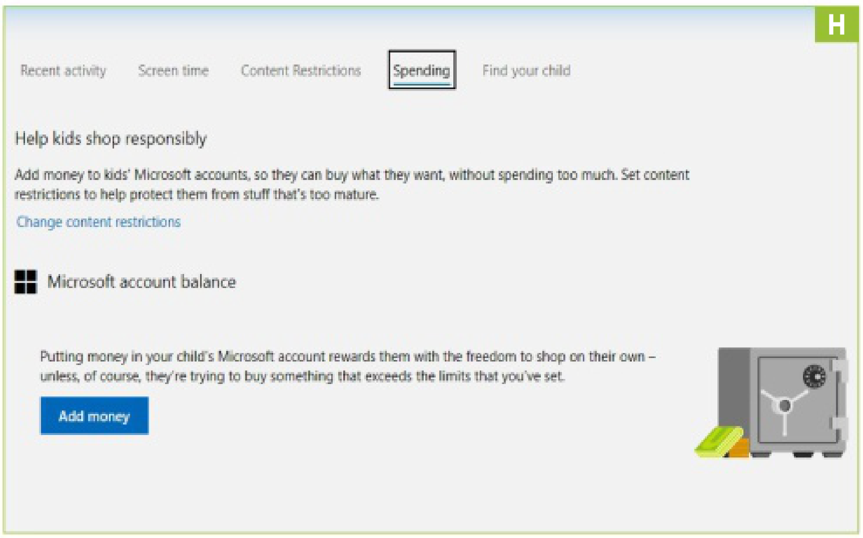
Xbox One

Windows 10

How much time can your child have each day across all of their devices, and when can they use them?

Day	Time limit
Sunday	Max scheduled
Monday	Max scheduled
Tuesday	Max scheduled
Wednesday	Max scheduled
Thursday	Max scheduled
Friday	Max scheduled
Saturday	Max scheduled

▨ Blocked 🟦 Allowed



Help kids shop responsibly

Add money to kids' Microsoft accounts, so they can buy what they want, without spending too much. Set content restrictions to help protect them from stuff that's too mature.

Change content restrictions

Microsoft account balance

Putting money in your child's Microsoft account rewards them with the freedom to shop on their own – unless, of course, they're trying to buy something that exceeds the limits that you've set.

Record Screen Action With the Game Bar

YOU'LL NEED THIS

WINDOWS 10
Access the Game Bar via the Start menu, or press Win-G.

TAKING A STATIC SCREENSHOT IN WINDOWS 10 is incredibly easy: Just press the Print Screen key, and whatever you see on your screen is copied to the clipboard, ready for you to paste into an image-editing program. To do something more advanced, you can turn to Windows 10's Snipping Tool, which enables you to do things such as just capturing an area of your desktop. But what about if you want to record the action happening on your screen? What if you want to make a video of what you see on your desktop?

While you could turn to a third-party app, you might be surprised to learn that Windows 10 has its own video capture tool built in. Part of the Game Bar component, the screen recorder is really designed for gamers looking to capture videos of their gaming, but there's nothing to stop you using it for other purposes if you want. Here's how to get started. –MARK WYCIŚLIK-WILSON

1 ACCESS THE GAME BAR

If you're not a gamer, you may never have investigated the Xbox and gaming-related aspects of Windows 10, but this is where to go if you want to start recording videos for free [Image A]. If you browse through the Start menu, you will find—or can search for—"Game Bar." To access the tool quickly, you can also use a keyboard shortcut: Just press Win-G.

2 CONFIGURE GAME BAR SETTINGS

Now you know where the Game Bar is, you might want to jump in and start recording straight away. It's worth spending a little time configuring a few options first, though. Go to "Start → Settings → Gaming" to go to the Game Bar section. Start by ensuring that the "Record game clips, screenshots, and broadcast using Game Bar" toggle is enabled [Image B].

3 CUSTOMIZE KEYBOARD SHORTCUTS

The Game Bar's keyboard shortcuts are incredibly useful. There's a number built into the tool, but you can also customize them. Scroll down the settings slightly, and you can see a list of default shortcuts—simply select any that you'd like to change, and enter the key combination you'd prefer to use instead [Image C]. Click "Save" when you've finished.

4 ENABLE BACKGROUND RECORDING

Usually, you will want to start a recording at a particular point and stop it when you've finished, but you may wish you could step back in time and start a recording slightly earlier. That's what "Background recording" is for. Enable it, and your PC constantly records, giving you the option of saving footage from 30 seconds (or more) ago to capture important action [Image D].

5 RESTRICT RECORDING LENGTH

When you start recording, it's easy to forget that you're capturing footage, and you may forget to stop the recording. To help avoid this, and make sure you don't completely fill up your PC's storage drive with recordings, you can place an upper limit on the length of the capture. Use the drop-down menu to choose anything from 30 minutes to four hours as the maximum length [Image E].

6 AUDIO RECORDING OPTIONS

When recording, it may well not just be video you are interested in—there is also audio to consider. In the "Recorded audio" section, you can choose between recording audio or not using the toggle, and use the checkbox to indicate whether audio from your microphone should be recorded as well. Beneath this, you can configure audio volume levels and recording quality [Image F].

7 VIDEO RECORDING QUALITY

As well as configuring the audio quality, you can also choose the video quality of your recordings. The first choice you have is between 30 and 60 frames per second, which affects smoothness, and beneath this, you can choose between "High" and "Standard" recording quality [Image G]. The final option you have is to choose whether or not your mouse cursor should be visible in recordings.

8 RECORD VIDEO FOOTAGE

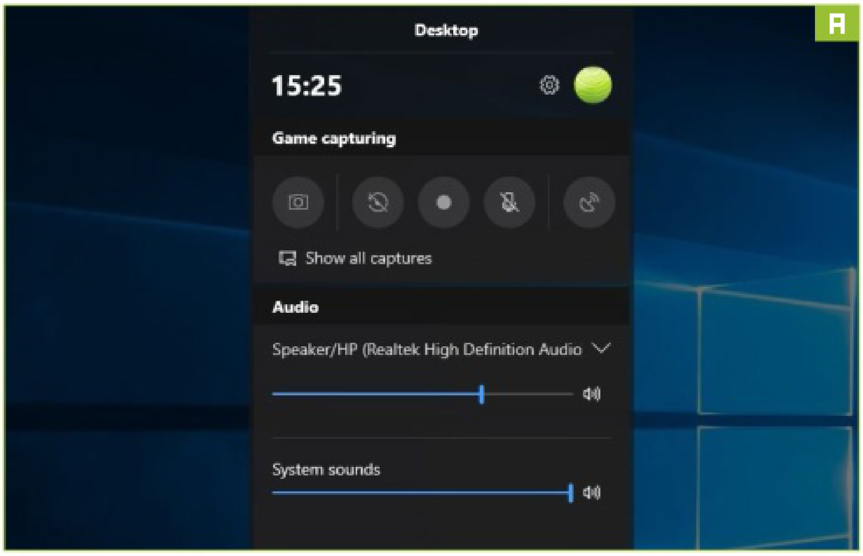
You're now ready to start recording. Either call up the Game Bar using Win-G, before pressing the "Record" button, or use a keyboard shortcut to start recording directly: Win-Alt-R by default [Image H]. Recording starts according to the settings you've chosen, but if you're recording application footage rather than in a game, check the box to enable "gaming features" for recording to continue.

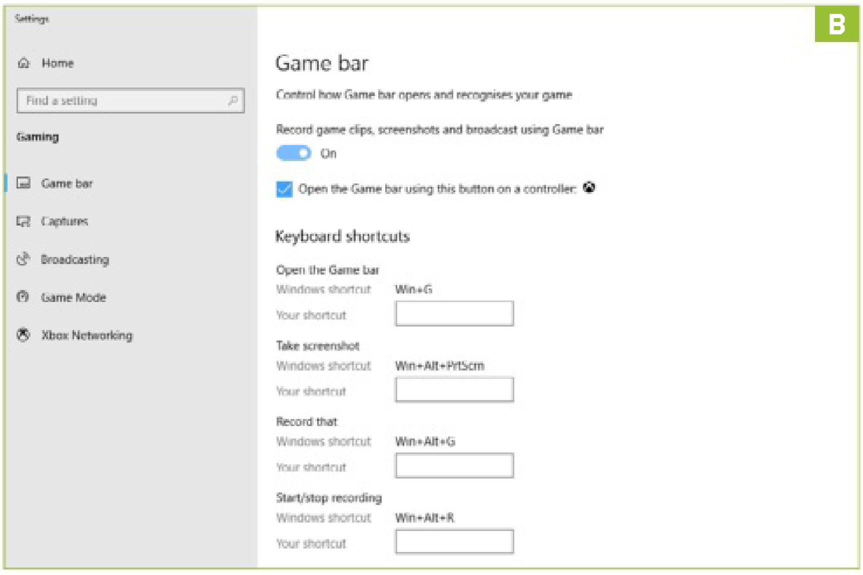
9 STOP RECORDING

During recording, you should play your game or use your apps as normal. When you are ready to stop recording, you can either press Win-Alt-R again, or you can use the recording pop-up that appeared when recording started. Click the "Stop" button, and a notification is displayed confirming that the recording has been saved in the capture folder.

10 ACCESS YOUR RECORDINGS

Your recordings are automatically saved to the capture folder, and you can access them immediately after you stop recording by clicking the pop-up that appears. Another option is to click "Show all captures" within the Game Bar, or to fire up the Xbox app, move to the "Captures" section, and browse through the videos that are listed.


A
Desktop
15:25
Game capturing
Show all captures
Audio
Speaker/HP (Realtek High Definition Audio
System sounds


B
Settings
Home
Find a setting
Gaming
Game bar
Captures
Broadcasting
Game Mode
Xbox Networking

Game bar

Control how Game bar opens and recognises your game

Record game clips, screenshots and broadcast using Game bar

On

☑ Open the Game bar using this button on a controller:

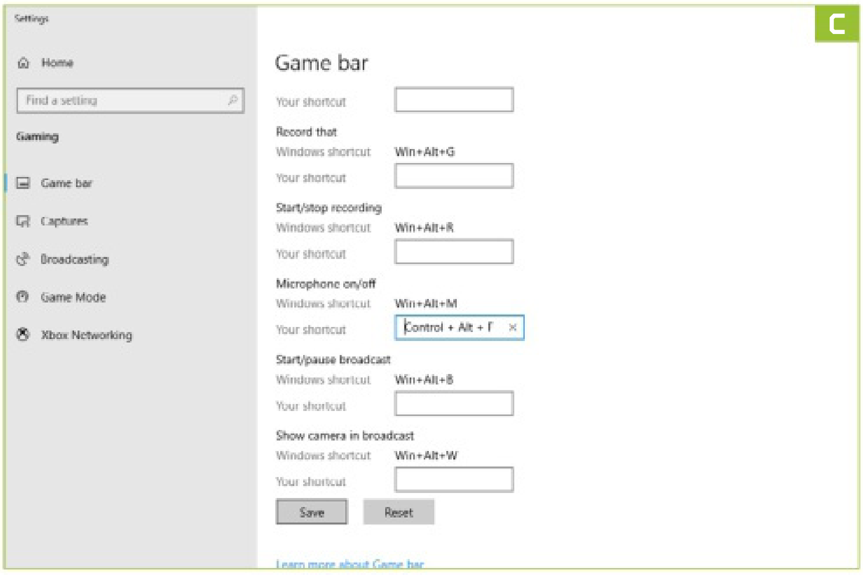
Keyboard shortcuts

Open the Game bar
Windows shortcut Win+G
Your shortcut

Take screenshot
Windows shortcut Win+Alt+PrtScrn
Your shortcut

Record that
Windows shortcut Win+Alt+G
Your shortcut

Start/stop recording
Windows shortcut Win+Alt+R
Your shortcut


C
Settings
Home
Find a setting
Gaming
Game bar
Captures
Broadcasting
Game Mode
Xbox Networking
Save
Reset
Learn more about Game bar

Game bar

Your shortcut

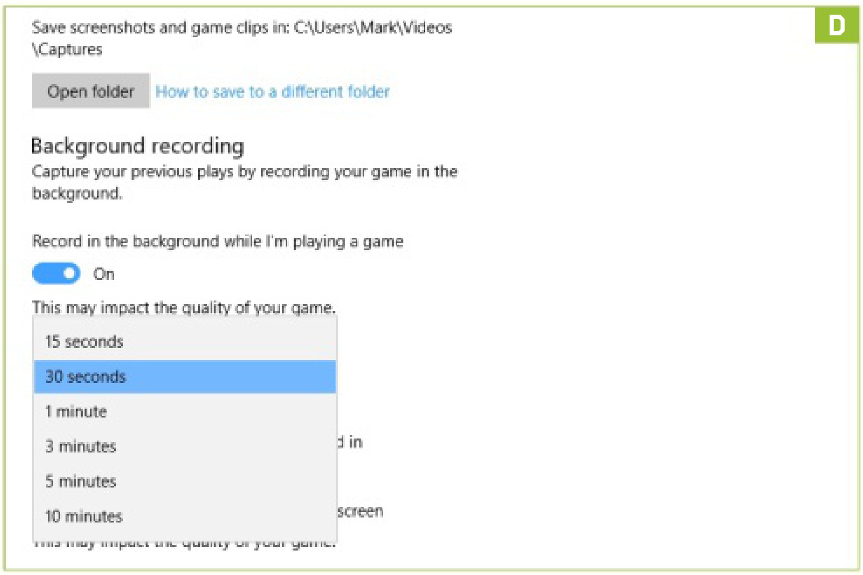
Record that
Windows shortcut Win+Alt+G
Your shortcut

Start/stop recording
Windows shortcut Win+Alt+R
Your shortcut

Microphone on/off
Windows shortcut Win+Alt+M
Your shortcut Control + Alt + F

Start/pause broadcast
Windows shortcut Win+Alt+B
Your shortcut

Show camera in broadcast
Windows shortcut Win+Alt+W
Your shortcut


D
Open folder
How to save to a different folder
15 seconds
30 seconds
1 minute
3 minutes
5 minutes
10 minutes

Save screenshots and game clips in: C:\Users\Mark\Videos \Captures

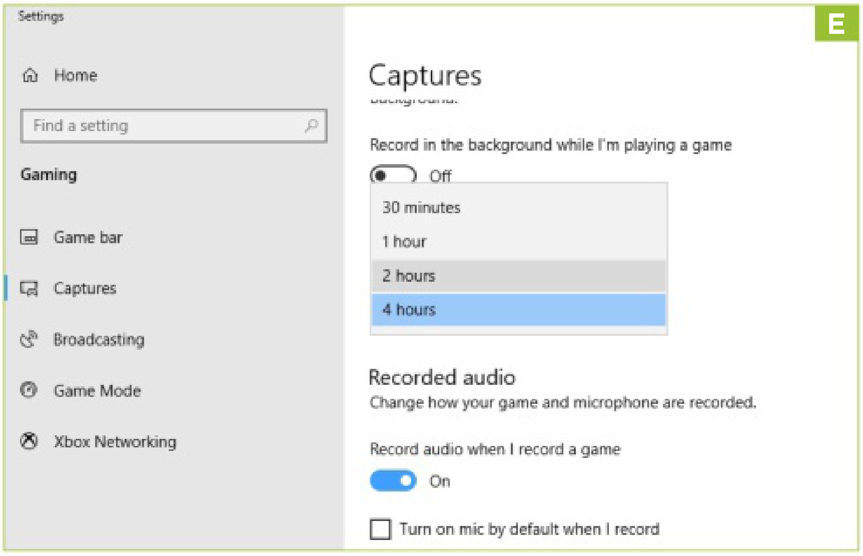
Background recording

Capture your previous plays by recording your game in the background.

Record in the background while I'm playing a game

On

This may impact the quality of your game.


E
Settings
Home
Find a setting
Gaming
Game bar
Captures
Broadcasting
Game Mode
Xbox Networking
30 minutes
1 hour
2 hours
4 hours

Captures

Record in the background while I'm playing a game

Off

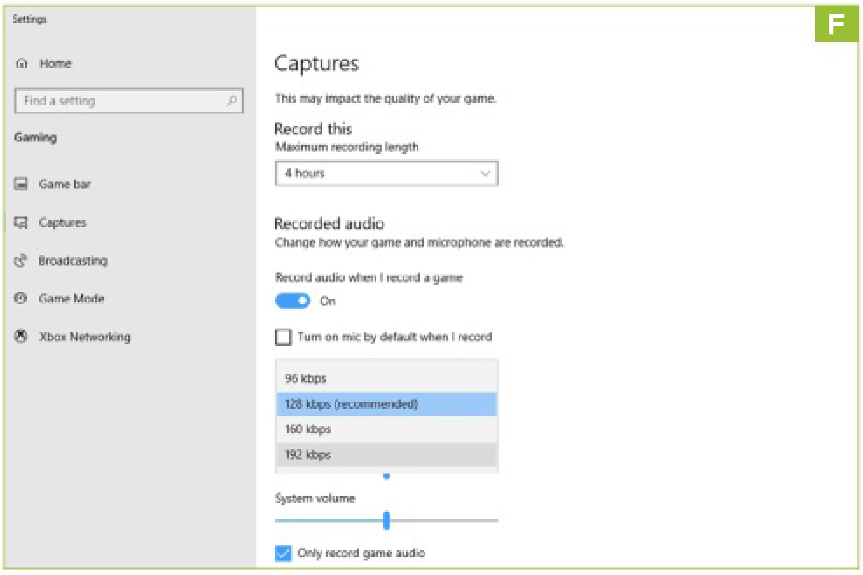
Recorded audio

Change how your game and microphone are recorded.

Record audio when I record a game

On

☐ Turn on mic by default when I record


F
Settings
Home
Find a setting
Gaming
Game bar
Captures
Broadcasting
Game Mode
Xbox Networking
96 kbps
128 kbps (recommended)
160 kbps
192 kbps

Captures

This may impact the quality of your game.

Record this

Maximum recording length

4 hours

Recorded audio

Change how your game and microphone are recorded.

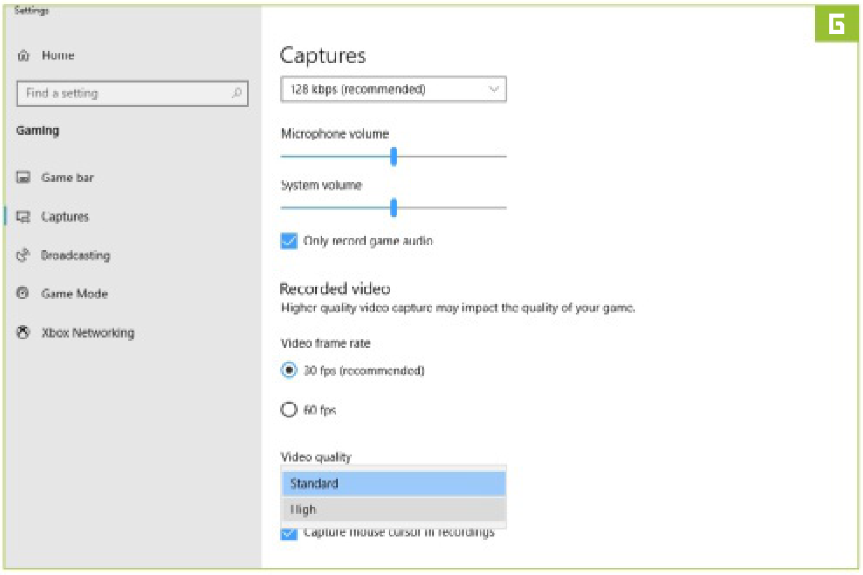
Record audio when I record a game

On

☐ Turn on mic by default when I record

System volume

☑ Only record game audio


G
Settings
Home
Find a setting
Gaming
Game bar
Captures
Broadcasting
Game Mode
Xbox Networking
Standard
High

Captures

128 kbps (recommended)

Microphone volume

System volume

☑ Only record game audio

Recorded video

Higher quality video capture may impact the quality of your game.

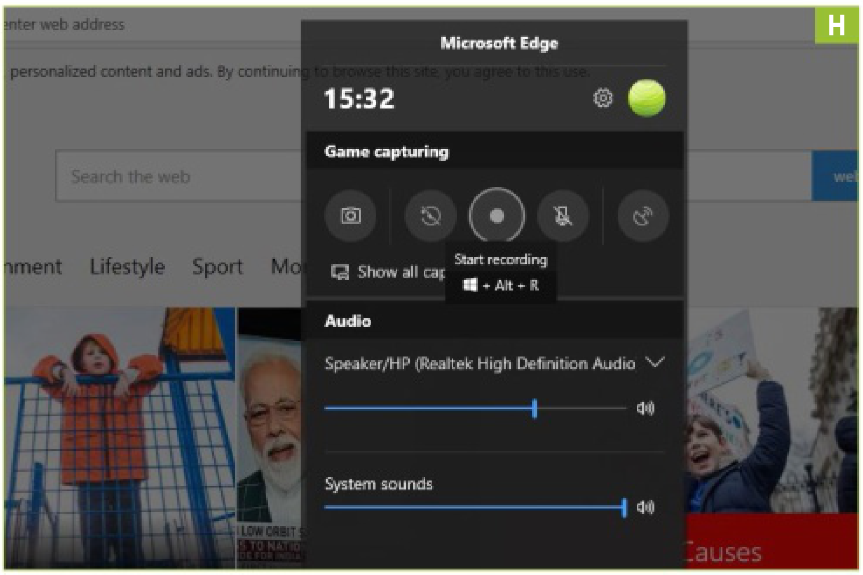
Video frame rate

● 30 fps (recommended)

○ 60 fps

Video quality

☑ Capture mouse cursor in recordings


H
Microsoft Edge
15:32
Game capturing
Show all cap
Start recording
+ Alt + R
Audio
Speaker/HP (Realtek High Definition Audio
System sounds
Search the web
Lifestyle
Sport

© MICROSOFT WINDOWS 10

Create a Paint Splatter Effect

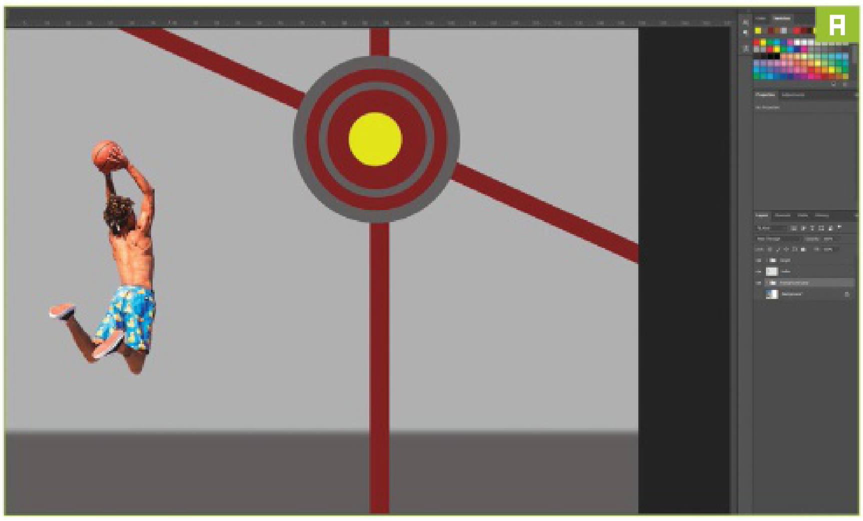
YOU'LL NEED THIS

ADOBE PHOTOSHOP
Subscribe to a suitable package at www.adobe.com.

ONCE, IF YOU WANTED TO PAINT IN NATURAL MEDIA, you did just that. Later, when computers were invented, you used Corel Painter. Now, natural media brushes are part of Photoshop, and you can smear, smudge, and blend your way across any image, creating something that's halfway between the art of the photographer and the portrait artist.

This kind of dynamic distortion makes it easy to convey movement in a still image, but it's easier to do so if there's implied motion there already. Whether it's a shot of an athlete making a jump mere mortals couldn't consider, or just someone running along a wall, an explosion of paint effects adds a velocity and a dynamism that transcends the static nature of photography.

The natural media brushes use the Brush tool to paint with, of course, but also the Smudge tool to smear the paint around once we've applied it. There's a relatively new Mixer Brush tool as well, which takes paint from the colors you've selected, as the Brush does, but also takes colors from the canvas it passes over, mixing the two together to simulate the way wet paint would behave. With a combination of these, plus downloaded brushes designed to behave like palette knives and ink washes, we can build up a natural-looking effect. **–IAN EVENDEN**



1 CHOICE OF PHOTO

A sense of movement is important here. It takes some photographic skill to impart motion to a still image, but it makes for a fun little project if you're able to spend an afternoon with your camera at the sports field or dog park. You need a complete figure, but don't worry too much about the framing, as we'll be cutting it out, and can move it on to a wider background.

2 SELECT, REFINE, REMOVE

Isolate the subject using the selection tool of your choice. With a decent amount of contrast between subject and background, we've always had luck with the Quick Selection tool, but our basketball player's amazing shorts (if you can't see, they have yellow rubber duckies on them) are a bit too close to the blue of the sky to provide a nice edge for the tool to latch on to. We resorted to ever-smaller brushes and a thumb permanently hovering above Alt to switch between adding and removing from the selection, chipping bits in and out until we reached for "Select and Mask" to smooth it out. Output the selection to a new layer.

3 BACKGROUND

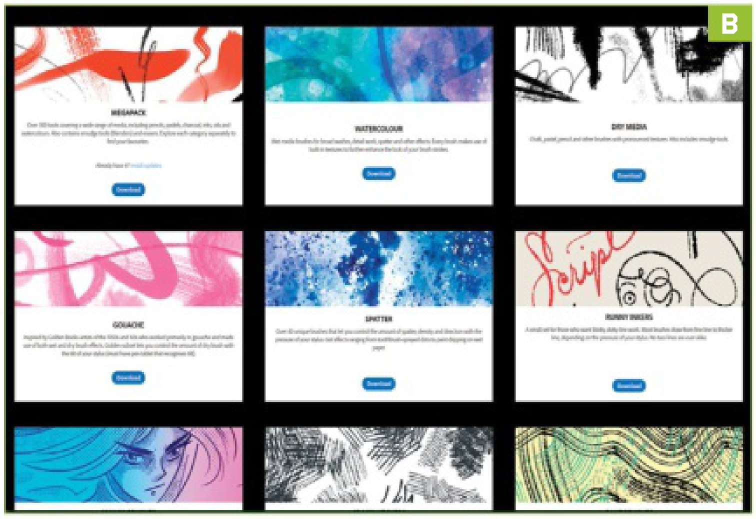
We've used "Image → Canvas Size" to turn a portrait document into a landscape one, then knocked up a quick background and target graphic using the Rectangular Marquee, Paint Bucket, and Free Transform tools [**Image A**]. It's not important for the effect we're creating, however. Everything here is on a separate layer, although we've grouped some for convenience. Save as a PSD file to preserve your layer structure.

4 BRUSHES

The liquid decomposition effect we're after calls out for some custom brushes. While the app comes with its own wet media brushes, they're not quite wet enough for the effect we're after. There are many Photoshop brushes available on the web, some commercial and others offered under Creative Commons licenses. Have a Google for "spatter brushes" and see what you find, or click "Get More Brushes" from the palette's menu—there are watercolor, ink, and spatter brushes there for the taking [**Image B**]. Load new brushes into Photoshop by opening the Brushes palette from the "Window" menu, then dropping down the palette's menu, and choosing "Import." Photoshop brushes are in ABR files, so you know which one to pick.

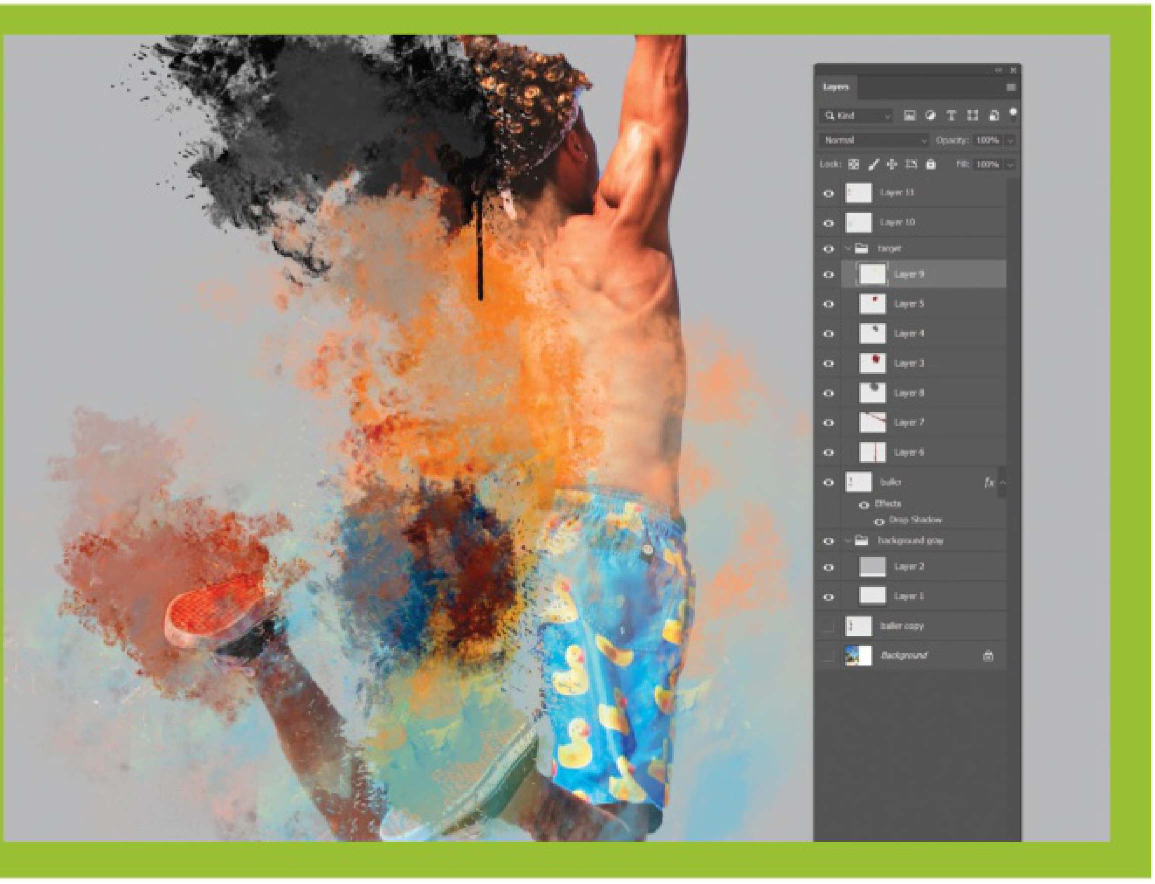
5 DROP AND PAINT

Once you've got some splattery brushes installed, you can start painting. On a new layer, use the Dropper tool to sample a color near the trailing edge



LAYERS FOR ALL

Making sure you know which layer you're on can be the difference between a successful effect and a tedious trip to the History palette to undo several steps because they've been painted in the wrong place. The Move tool has an "Auto Select" function, which can be changed between layers and groups of layers, and this is useful for discovering which layer particular pixels live on. Just click with Move, and the layer below it is selected. While there's nothing like proper layer discipline—grouping and renaming layers so there's no ambiguity about what part they play in your composition—shortcuts like this are essential if you want to avoid getting frustrated while the creative juices are flowing. Just keep everything to a separate layer, and you'll be fine.



of your subject—from the foot or the leg if it's a leaping athlete. Then use the Brush tool, in conjunction with your new brushes, to make a paint blob. A single click might do it, but make sure it's placed on the border between your subject and the background. Once you've got the hang of it, make another, then more—change the color using the Dropper, and the brush tip using the Brushes palette, and build up a mixture of paint splats of differing colors. (Beware: Some brushes are meant for the Smudge tool only; those locked to a tool have an identifying icon at their top-right.)

6 SMUDGE

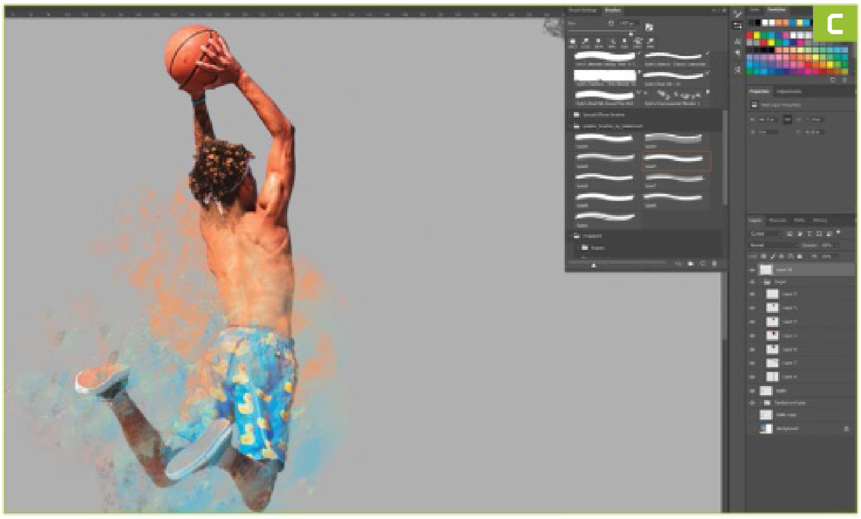
The Smudge tool enables you to push the paint around as though it's a wet medium. It can be quite processor-intensive, so is best used in short bursts. Choosing a brush that's tied to the Smudge tool can often give a great result, but it's worth playing with it first, so you know exactly what effect it's going to give. Try smudging all the paint splatters around your composition's subject, going back to the Brush tool to create more mess if you're in danger of smudging it all away. This way, you'll build up a cloud of paint around your subject. By keeping it on the trailing edge, you'll underline the sense of movement in the image [**Image C**]. Remember that a brush can not only be resized, but also rotated, from the drop-down at the top-right of the interface. Smudge brushes often rotate after every click, making it easier to avoid a repeated pattern.

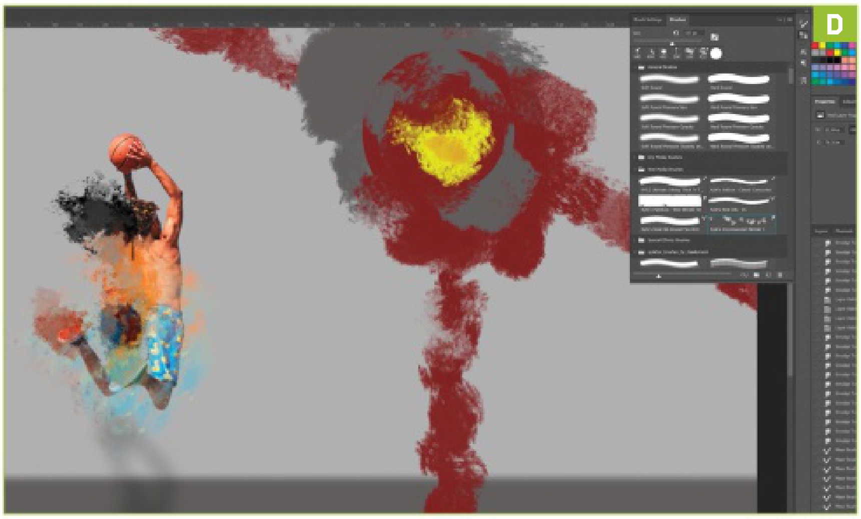
7 ERASE

If you want to go further, you can erase parts of your original subject from beneath the painted and smudged layer, giving the impression that the athlete has broken down into a cloud of paint while flying through the air. To do this, simply use the Eraser tool on the layer containing the subject—you might want to duplicate it once to preserve it. By erasing the subject in this way, we allow the background to show through any gaps in the smudged paint layer, giving the impression the subject is moving so fast it's dissolving.

8 FINISHING TOUCHES

There are a few things you can do to finish off your composition. If your subject is leaping into the air, for instance, you can paint a darker area beneath it to act as a shadow. Alternatively, you could use a Layer Style to achieve the same effect. We've done some smudging on the background we created, a target for our jumping baller to aim at, and we've blended two layers' worth of smudged paint together using the Linear Burn blend mode to intensify the colors [**Image D**]. Save the final PSD file so you can come back later, and export your artwork as a JPEG or PNG for sharing online using "File → Export as." ⏻





© ADOBE PHOTOSHOP

BUILD IT

CHRISTIAN GUYTON, STAFF WRITER

The Media Mandate

We set out to build an affordable media center—the perfect rig for your living room

LENGTH OF TIME: **2-3 HOURS**

LEVEL OF DIFFICULTY: **MEDIUM**

THE CONCEPT

IT'S EASY FOR US to forget sometimes that people use computers for more than just gaming, benchmarking, and editing magazines. And that, sometimes, people might even plug their computers into a screen other than a monitor. So, when we got our hands on Fractal Design's Node 202 case, we knew what we had to do: Build a sleek, powerful, but inexpensive media center, designed to sit snugly beneath the television. The brief for this "Build It" was a little tricky, though—it needed to be a PC that didn't look like a PC. We needed a Mini-ITX motherboard, HDMI port, and a processor with onboard graphics. Oh, and keep the price as low as possible, thank you very much.

Media center PCs are nothing new, but the components that can be used to make them are continually evolving—albeit at a slower rate than parts for beefy gaming PCs. There's little to no precedent to fit a GPU inside one of these dinky rigs, and as more processors with onboard graphics are released, so expands our selection of potential builds. The "perfect" media center build may not exist; indeed, builds like this are already competing with home consoles and high-end smart TVs. It's complicated, heavily populated ground. The advantage of these computers is the advanced degree of customization and flexibility—unlike consoles and smart TVs, they have access to different operating systems, a wider selection of software, and can use internet browsers in a way that doesn't make you want to cut your hands off. They might not be as suitable for gaming as consoles, thanks to the lack of a dedicated graphics card, but they have the added bonus of easier repairs and upgrades—no waiting for the next console generation here; if you want to upgrade your processor, you can just go right out and do it.

LESS IS MORE

FRACTAL DESIGN has knocked it out of the park again with the Node 202. The Swedish manufacturer has long been the top dog in case design, and this is no exception. The 202 serves as the basis for this build; simple but elegant, carefully designed to inhabit any space without being obtrusive. In appearance, it blurs the lines between PC and console, making it perfect for a media center build. It's tiny, though; a thin little unit that demands care and minimalism when it comes to internal components. There's no need to include a GPU in this build, but the 202 comes with a little box of accessories that accommodate such power; most importantly, this box contains an L-shaped adapter that allows for vertical mounting of the GPU—a necessity, given the case's small overhead. The case as a whole can be oriented horizontally or vertically, with either a plastic base to mount it upright, or stick-on rubber feet.

And minimalism is what we've got. Asus's ROG Strix X470-I motherboard is a simplistic affair, but it packs everything we need: an HDMI output, four USB 3.1 ports, AM4 compatibility, and full support for all the RAM. It's an adorable unit, too—measuring a dainty 6.22 x 6.22 inches, with a stripped-back appearance that doesn't sacrifice performance for aesthetics. It's the perfect board to support the AMD Athlon 220GE, which comes with integrated Radeon Vega 3 graphics, and its own cooler inside the box—a low-profile fan and heatsink that will easily fit inside the Node 202.

There's not much else that needs including here—the 202 comes with an integrated 450W power supply, and we're forgoing a GPU in favor of the Athlon 220GE's own processor graphics. For the SSD, we've got a SATA Adata Ultimate SU800 with 512GB of storage—there's no space for a hard drive inside this case, and an M.2 drive would drive the price up too much.

INGREDIENTS

PART		STREET PRICE
Case	Fractal Design Node 202	$134
Motherboard	Asus ROG Strix X470-I Gaming	$207
CPU	AMD Athlon 220GE	$68
CPU Cooler	Stock	N/A
Memory	Corsair Vengeance LPX 2x 4GB 2,400MHz	$49
PSU	450W Fractal Design Integra SFX	N/A
Storage	Adata Ultimate SU800	$60
OS	Windows 10 Home 64-bit	$100
Total		$618

1

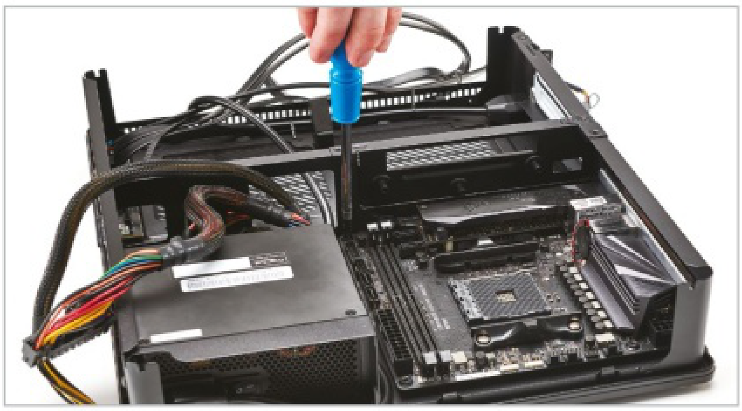
THE BARE NECESSITIES

AS ALWAYS, we start with a stripdown of the case. Lay it on its side, and remove the four case screws, then flip the case over, and remove the large plastic side. The Node 202 comes with an integrated PSU, which feeds through to a standard three-pin power port in the opposite corner of the case. You can remove the PSU if you like, but you'll struggle to find another that fits for a sensible price. There aren't any case fans to worry about, but the cabling is all bundled together, so free that up first. Fractal Design knows how to do cable management; there are numerous slots for cable ties inside this case. If you want to install fans, this case has the capacity for two 120mm fans in the GPU chamber—but these are complicated to mount, and for us, the PSU and CPU fans suffice. You may also want to remove the SATA drive bracket next to the PSU, as you'll need it later.

2

BOARD MEETING

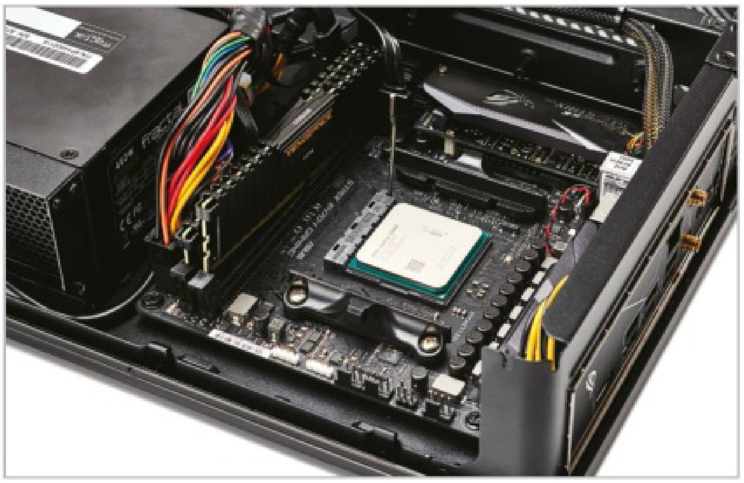
ORDINARILY, we advise installing some components on the motherboard before sliding it inside the case, but not today—the overhead inside the 202 isn't exactly spacious, and the power cables can get in the way. Pop in the rear I/O shield, then lower the motherboard into place; this might require some finger gymnastics to keep the PSU cables out of the way. The mobo screws down at four points, and the screws come in the 202's accessories box. Plug in the two mobo power cables, feeding the eight-pin CPU power connector around the edge of the mobo chamber, while the ATX cable can plug in directly. Fold the remaining cables into the space between the PSU and the metal plate that divides the case in two, and secure them with a cable tie—leave the SATA power cable free for now. The cables from the front I/O can be plugged in, feeding any excess length into the GPU cavity.



3

HAPPY MEMORIES

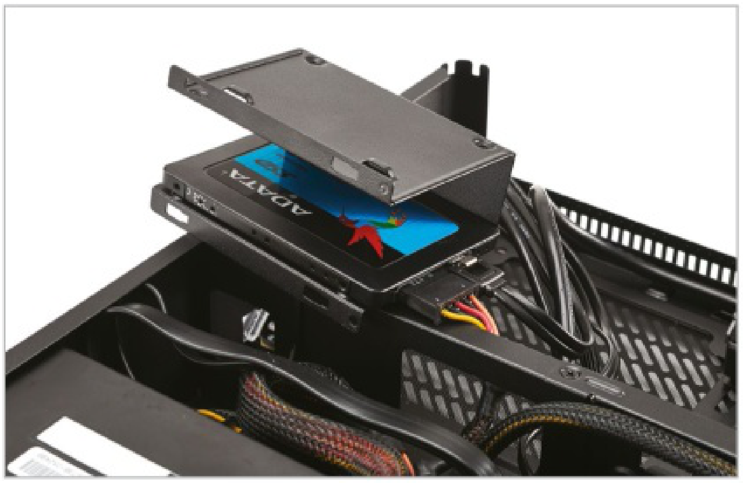
TIME TO INSTALL some components on the motherboard. The CPU can go in first—the Athlon 220GE drops neatly into the AM4 dock, and locks into place when the clasp is lowered. We'll install the cooler later, as it's the bulkiest component. For now, release the clasps on the memory slots, and install the RAM. You might need to shift the ATX power cable out of the way; the 202 is undeniably cramped inside. Push down the sticks until they click into place, then tidy up the cables as much as you can. This memory isn't the cheapest option available, but with low CAS latency and 3,200MT/s, it's speedy and effective. If you want to install a GPU, do it now; plug in the L-shaped adapter and extender from the 202's box, then remove the rear I/O covers, and plug in the card.



4

BRACKETEERING

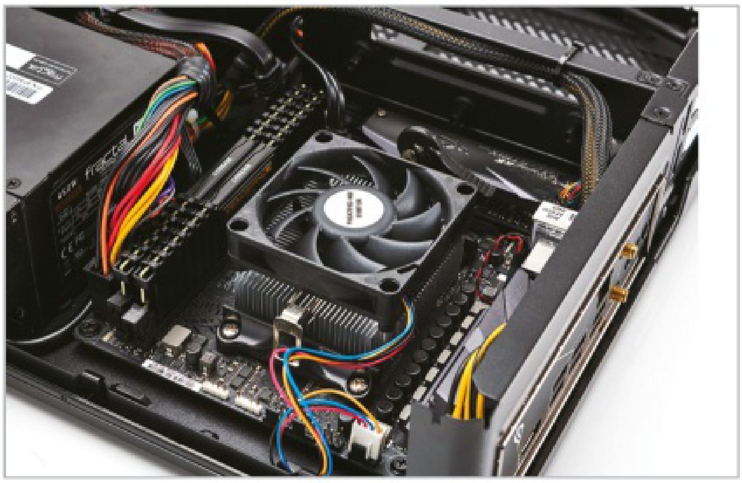
THIS NEXT STEP can be a tad tricky. Take the SATA drive bracket, and screw in the SSD on the inner side, ensuring that it's aligned correctly. When the bracket is returned to the case, the drive needs to be on the opposite side of the divider to the PSU, pointing toward the motherboard. Once you're sure it's in the correct position, feed through the power and SATA cables from the PSU and motherboard respectively, and plug them in before slotting the bracket back into place and screwing it down. It's easiest to rest the bracket on the divider before screwing it back into place, so you can be certain the cables will stretch. If you have a short SATA cable to hand, we're recommend using it. Keeping the total cable length inside this case to a minimum is a good plan.



5

STOCK AND LOAD

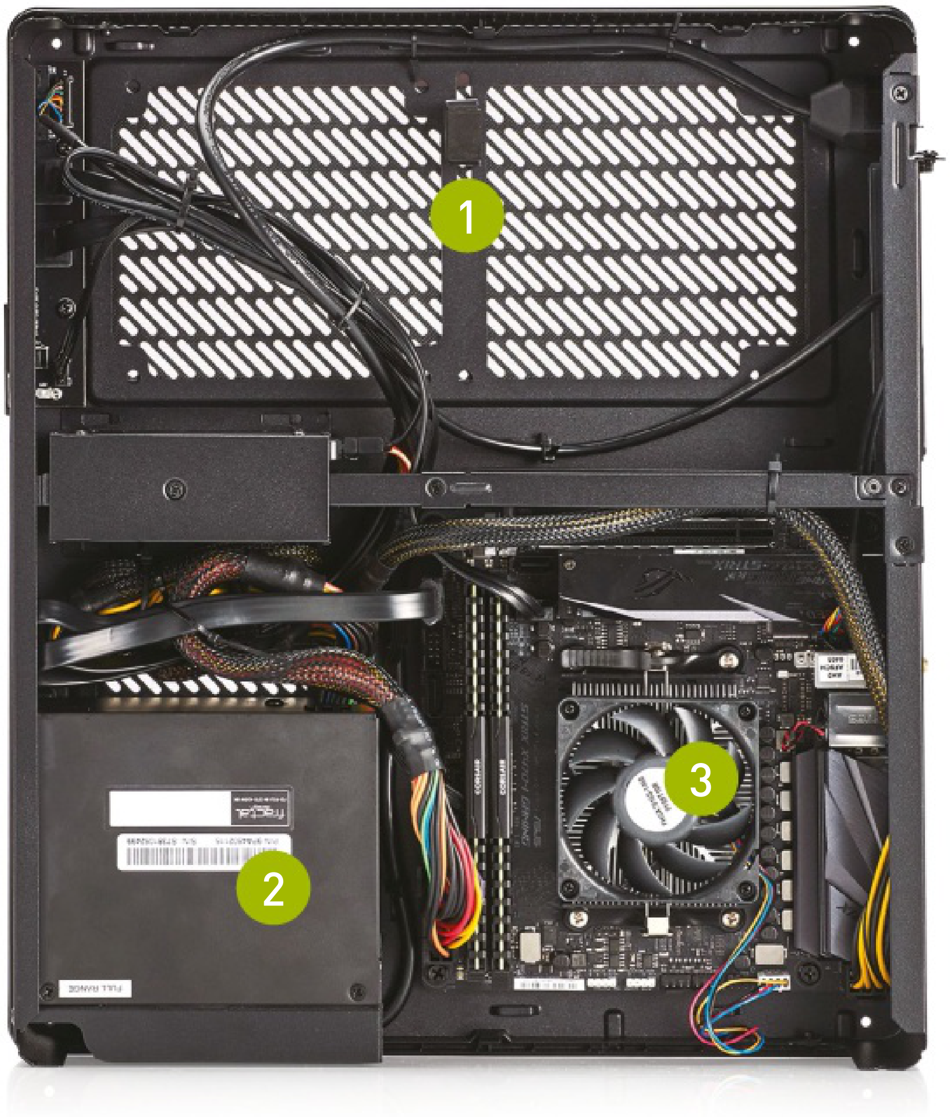
EVERYTHING ELSE IN PLACE, it's time to install the CPU cooler. We're using the stock Athlon cooler, which isn't particularly exciting, but will fit directly on to the bracket that comes fitted on the Strix X470-I Gaming. Be careful when removing this cooler from the box—it comes with a neat little lattice of thermal paste already applied to the base of the heatsink, so take care not to get any on your fingers. This might not look like a lot, but it'll spread out evenly once the processor heats up, so there's no need to apply any extra paste. Place the cooler in the center of the CPU, then align the bracket so that it attaches to the motherboard on both sides, before turning the plastic handle to clamp it down. Once it's in place, plug it into the CPU fan connector on the motherboard.



6

TIDYING UP

THIS BUILD MIGHT BE finished, but we're not done yet. Reassembling the 202 isn't as simple as we'd like—no pop-off side panels or thumbscrews here, sadly. Before we seal the case up, it's worth taking time to arrange your cables; the front I/O wires can be neatly bundled with a cable tie, and any loose cables should be tucked away where possible. In theory, this build shouldn't need updating for a long time, so ensuring it's tidy inside is a must. Once you're satisfied, lower the plastic cover back on to the case, turn it over—carefully!—and screw it on. If you want to mount it upright, you're done; place it on the plastic mount, and it's ready to plug in and use. If you'd prefer to lie it flat, cut out the rubber feet, and peel off the sticky backs to secure them on the bottom of the case.



1 There's ample space for a GPU here, should you decide you'd like to do some proper couch gaming on this rig. It's a fairly complicated procedure, however, requiring the removal of the other side of the case and the adjustment of a support peg to fit the exact size of the card you use.

2 The aptly-named Integra SFX PSU pumps out all the power a small build like this needs. If you'd prefer a flashier compact PSU, the Node 202 can also be purchased without a power supply for just $80.

3 The Athlon 220GE's integrated graphics can handle standard online browsing and streaming perfectly well at an affordable price. The stock cooler does a decent job of keeping the temperature down, too.

MEDIA MADNESS

WELL, THIS CERTAINLY isn't a gaming PC. Can it run games? Just about, but it barely made it through our benchmarks, which use ultra settings at 1080p. Dialing all the graphical settings down to minimum in *Rise of the Tomb Raider* and running it in 720p resulted in a more workable frame rate, but the game looked eerily reminiscent of *Runescape* circa 2003. That's all right, though—this wasn't designed to be a gaming computer. As a media center, it does the job perfectly, running quietly and loading fast.

The Node 202 looks great, but it isn't easy to work in. It's packed with nice features and innovations from Fractal Design, such as the perpendicular GPU mounting system and the SSD shroud, but they don't make it any simpler to build with it. Cable management is easier than in some other Mini-ITX cases, at least. Our finished build looks efficient and tidy inside, with the minimal RGB effects on the motherboard mostly concealed by the 202's black plastic exterior.

If we hadn't wanted to keep the price down, we'd have considered installing a GPU. Swapping out the CPU for something with a bit more muscle, and adding a GTX 1060 or 1070 would make this a perfectly capable rig for gaming—perhaps a family-oriented console replacement, perfect for multiplayer sessions in front of the TV. Streaming TV and movies is a snap, and the SSD has sufficient storage for a reasonable number of video files, should downloading be your preferred method. A keyboard with an integrated trackpad or a wireless controller might be useful, to ensure ease of use from your favorite armchair.

There are some other things we might change, if we had a chance at a do-over. MSI, Gigabyte, and ASRock all offer cheaper Mini-ITX boards, so if gaming is fully off the table, the extra functionality of the X470-I isn't necessary. Our choice of mobo also offers dual M.2 slots, which wasn't needed for this build—an M.2 SSD would have been easier to install than the SATA drive we chose, but it would have driven the price up.

If you're a real glutton for punishment, there's arguably no need to install Windows. A Linux-based OS is cheaper, although it would involve far more software wrangling. There are still plenty of useful media center programs that can run on Linux, such as home cinema app Kodi. Chrome is available for 64-bit versions of Ubuntu, too. Overall, this build was a modest success—it looks good and it does the job we wanted it to—but there's definitely room for improvement. ⏻

BENCHMARKS

	ZERO-POINT	
Cinebench R15 Multi (Index)	541	373 (-31%)
CrystalDisk QD32 Sequential Read (MB/s)	540	556 (3%)
CrystalDisk QD32 Sequential Write (MB/s)	372	520 (40%)
Rise of the Tomb Raider (fps)	5	7 (40%)
Total War: Warhammer II (fps)	3	4 (33%)
Tom Clancy's Ghost Recon Wildlands (fps)	2	N/A
3DMark: Fire Strike (Index)	1,183	1,304 (10%)

0% 10% 20% 30% 40% 50% 60% 70% 80% 90% 100%

Our zero-point consists of an Intel Core i3-8100, 8GB of Team Vulcan DDR4 @ 2,400, and a 120GB Kingston SSDNow UV400. All tests were performed at 1080p on the highest graphical profile.

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TESTED. REVIEWED. VERDICTIZED.

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CORSAIR
ONE

CORSAIR ONE PRO i180
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CORSAIR
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The Corsair One Pro is a delightfully compact, yet powerful, system.

Corsair One Pro i180

There's no messing with this compact workstation

IT'S RARE THAT WE fall head-over-heels in love with a pre-built system like this. And yet, as we look at the Corsair One Pro, silently flashing its subtle RGB front plate on our test bench, we can't help but feel a pang of guilty longing. Corsair's newest and best PC yet is like a childhood crush; cool and attractive on the outside, but an absolute monster on the inside, just waiting to be unleashed. Middle school was a tough time for us, OK?

We're not joking about the One Pro, though. The i180 model we have in for review is packing some serious heat beneath its burnished metal exterior. For starters, our unit has an MSI-branded RTX 2080 Ti GPU, making short work of 4K gaming. The One Pro can even feed four 4K monitors simultaneously. Processor-wise, we've got a 24-thread Intel Core i9-9920X mounted on an X299E motherboard, with 32GB of RAM at 2,666MHz. In other words, this is a beast of a machine. You wouldn't know from looking at it, though. The One Pro's 12-liter case is elegant yet minimalistic, consisting primarily of bead-blasted aluminum with a gray matt finish, and triangle-patterned ventilation on either side of the tower. It's an unmistakably sci-fi product, running quietly thanks to its single top-mounted fan. The CPU and GPU are cooled with Corsair's own AIO units, with radiators mounted on either side of the case. The One Pro runs toasty, but that's OK; it's designed to handle the heat. It's a trade-off: lower volume in exchange for higher temperatures.

One of the One Pro's most impressive features is the elegant use of space. Cable management is smart throughout, and the ASRock motherboard vertically mounts the boot drive, a 960GB Samsung M.2 SSD, to help with cooling. The 2TB hard drive sits in a small tray beneath the mobo. The graphics card? Oh, it's plugged into a flexible connector that bends around the motherboard, where it's mounted against the mobo's rear side. Genius. The case's footprint is almost breathtakingly compact, measuring just 7.9 inches long and 6.8 inches wide.

Upgrading isn't impossible, but would be a worthy trial for any seasoned PC tinkerer. The lid of the case pops off with a release button, and the side panels are easily unscrewed, but from then on it gets much trickier. The motherboard only takes SO-DIMM RAM, which limits upgrade options. Swapping out the CPU or storage shouldn't cause too much grief, but replacing the GPU is sure to be a demanding process—Corsair warns that doing so will void your warranty, too. In fairness, there should be no need to upgrade a 2080 Ti for quite a while.

In terms of physical interactivity, the One Pro has all you're likely to need. The rear I/O packs three DisplayPort 1.4 outputs, six USB ports (one of which is a Type-C connector), and two Ethernet ports, as well as the usual selection of 3.5mm jacks. The front I/O is small and simple: a headphone jack, two USB ports, and an HDMI port, specifically for VR headsets. Yes, the One Pro is VR-ready, and it has the graphical power to make VR gaming a smooth experience.

The true judge of this PC is how well it measures up to its intended purpose. This is a workstation PC that will comfortably handle 4K video encoding or high-end rendering work. Our ray-tracing tests resulted in satisfying performance, too; this system won't struggle with graphically demanding titles. So, it's amazing—and has a price tag to match. The One Pro i180 retails at $6,799. No, we're not crying. It's just eyeball sweat. Could you build this yourself? Sort of. Some of the components are proprietary tech that you can't buy online, but we ran the numbers: A build with comparable internal hardware would likely cost you barely over half the i180's price tag. Yes, that's a significant price disparity, but good luck creating a build this sleek and compact. **–CHRISTIAN GUYTON**

VERDICT
9
KICK ASS!

Corsair One Pro i180

THE ONE Powerful graphics; inspired use of internal space; runs quietly; looks great.

NO FUN Brutal price point; upgrading isn't exactly easy.

$6,799, www.corsair.com

BENCHMARKS

	ZERO-POINT	
Cinebench R15 Multi (Index)	2,178	2,450 (12%)
CrystalDisk QD32 Sequential Read (MB/s)	3,136	3,141 (0.2%)
CrystalDisk QD32 Sequential Write (MB/s)	2,126	2,360 (11%)
3DMark: Fire Strike (Index)	6,988	8,468 (21%)
Rise of the Tomb Raider (fps)	68	85 (25%)
Total War: Warhammer II (fps)	42	58 (38%)
Tom Clancy's Ghost Recon: Wildlands (fps)	38	49 (29%)

0% 10% 20% 30% 40% 50% 60% 70% 80% 90% 100%

Our zero-point consists of an Intel Core i9-7900X, 32GB G.Skill RipJaws V series DDR4 @ 3,000, an MSI GeForce GTX 1080 Ti Gaming X, and a 512GB Samsung 960 Pro PCIe SSD. All tests performed at 4K at the highest graphical profile.

SPECIFICATIONS

Processor	Intel Core i9-9920X
Graphics	Nvidia GeForce RTX 2080 Ti
RAM	32GB (4x 8GB) Corsair Vengeance SO-DIMM @ 2,666MT/s
Motherboard	ASRock X299E-ITX/ac
Primary Storage	960GB Samsung PM981 NVMe M.2 SSD
Additional Storage	2TB Seagate ST2000LM015 Barracuda SATA HDD
Cooling Solution	Corsair One AIO cooling
PSU	Corsair SF750
Case	Corsair gray aluminum
Warranty	Two years

An attractive mid-range pre-built with a price cheaper than building yourself.

iBuyPower Gaming RDY SLIIBG213

Big bang for your buck

IBUYPOWER IS CARVING out a share of the pre-built market by being reactive, building well-designed PCs, and pricing its rigs around (or in some cases below) DIY costs. It has shown a willingness to listen to complaints from enthusiasts and professionals, and course-correct accordingly, which is seen to nice effect here with the Gaming RDY SLIIBG213.

Let's start on the surface. The SLIIBG213's case, the Slate 2, finds a nice balance between "gamer" aesthetic and clean industrial design. The front panel gives the appearance of brushed gunmetal, vividly bisected by two slashes of RGB, with the iBuyPower logo tastefully etched near the bottom. It's a good look, and blends form with function: The front panel is also host to a number of fairly broad exhaust vents, allowing air to travel horizontally through the machine.

The side panel is a beautiful pane of tempered glass, giving a view of the spacious interior. While it's nice to see a machine that isn't so crowded that it incites thermal panic, the components take up so little of the interior real estate that you wonder if the form factor couldn't have been reduced. The Asus B360M motherboard looks like an island tucked in one corner of the capacious case, with swaths of unused territory on both sides.

The upside of all that space is that it makes tinkering with the internals a breeze. There's no worry of jarring cables loose while you try to squeeze your fingertips into tiny spaces between parts, and the interior is a cinch to access, too—just remove four thumbscrews on the tempered glass side panel, and the majority of the architecture is exposed to your whims, minus the PSU and HDD storage bay, which are concealed behind a beefy custom PSU shroud.

Mounted to the mobo you'll find a Core i5-9400F, squarely in the middle of Intel's ninth-gen Coffee Lake offerings (the "F" indicates that it lacks integrated graphics, hardly a concern in a gaming PC). It's a great chip for balancing price and performance, and part of how iBuyPower can keep the MSRP for this machine close to the $1,000 mark (the current retail price on its website is $1,149).

Naturally, the GPU selection is another critical piece of that price point. iBuyPower has opted for the low end of the RTX family, the 2060, meaning you get dedicated support for ray tracing and DLSS, paired with capable performance at QHD. Alternately, it means that you can push massive frame rates at 1080p if you've invested a bundle of cash in a monitor with a killer refresh rate, and you value FPS more than resolution.

The most impressive part of that reasonable price tag, however, is the DIY comparison. Without taking the pack-in mouse and keyboard into consideration, pricing up a similar machine ran us just in excess of $1,200. The SLIIBG213's $1,149 by comparison isn't a massive difference, but given that you're essentially getting an SI to build your machine (not to mention a three-year warranty) for $50 less than it would cost to build yourself, it's a pretty remarkable number.

If there's an Achilles heel here, it's that the SLIIBG213 isn't a particularly future-proofed machine. While the motherboard will accommodate a higher-end CPU than the included i5-9400F, it doesn't support overclocking, and although the 600W PSU provides ample juice for the stock configuration, it doesn't leave you a tremendous amount of overhead if you do want to start piling in more high-end components. We also would have appreciated a little more storage space—in an era when games can consume more than 100GB of storage apiece, 500GB looks pretty slim.

As its name suggests, the Gaming RDY SLIIBG213 is begging to be plugged into a wall, have some peripherals attached, and dive into your Steam library. If you're looking for a machine in the $1,000 range that will secure you a spot firmly in the 1440p era of gaming, you'd be hard-pressed to find a better option without building it yourself, and iBuyPower is more than happy to save you some labor (and even a little cash). **–ALAN BRADLEY**

VERDICT
9

iBuyPower Gaming RDY SLIIBG213

➕ READY UP Smart component selection; 1440p ready; intelligent, attractive design.

➖ STUCK IN QUEUE Lacks a future-proofed motherboard; limited storage.

$1,149, www.ibuypower.com

BENCHMARKS

	ZERO-POINT	
Cinebench R15 Multi (Index)	959	1,051 (10%)
CrystalDiskMark QD32 Sequential Read (MB/s)	3,422	524 (-85%)
CrystalDiskMark QD32 Sequential Write (MB/s)	1,706	470 (-72%)
3DMark Fire Strike Extreme (Index)	9,128	8,705 (-5%)
Shadow of the Tomb Raider (fps)	71	66 (-7%)
Total War: Warhammer II (fps)	66	62 (-6%)
Metro Exodus (fps)	42	39 (-7%)

0% 10% 20% 30% 40% 50% 60% 70% 80% 90% 100%

Our zero-point consists of an Intel Core i5-8400, 16GB Corsair Vengeance LPX series @ 2,666, an MSI GeForce GTX 1080 Armor, and a 500GB Samsung 960 Evo PCIe SSD. All tests performed at 1440p at the highest graphical profile.

SPECIFICATIONS

Processor	Intel Core i5-9400F
Graphics	Nvidia GeForce RTX 2060 OC 6GB GDDR6
RAM	16GB Adata DDR4-2666
Motherboard	Asus TUF B360M-Plus Gaming S
Primary Storage	500GB WD Blue SSD
Cooling Solution	iBuyPower 120mm RGB liquid-cooling system
PSU	600W 80 Plus Gold
Case	iBuyPower Slate 2
Warranty	Three-year standard warranty service

MSI GTX 1650 Gaming X 4G

Nvidia's new GPU brings a modest boost in performance

THE GEFORCE GTX 1650 was inevitable, considering none of the other Turing GPUs can fill the role of a budget graphics card. This is likely the final implementation of the Turing architecture (at least on 12nm). The GTX 1650 uses a new TU117 GPU, which is a smaller and thus less expensive variant of the TU116 that powers the GTX 1660 and 1660 Ti cards. The key differences relative to the 1660 line are in the memory configuration and number of SMs (streaming multiprocessors).

As expected, the GTX 1650 has 4GB of GDDR5, clocked at 8GT/s—the same speed as the GTX 1660 as well as the previous-generation GTX 1060 cards. Four active memory controllers on a 128-bit bus give it 128GB/s of bandwidth, slightly more than the GTX 1050 Ti.

Nvidia is typically conservative with its reported boost clocks, with most cards running well above the given speed. The "stock" GTX 1650 has a boost clock of 1,665MHz. That's less than the GTX 1060 cards, but roughly 50 percent faster than the GTX 1050. The GTX 1650 is also designed to run without a six-pin PCIe power connector, though factory overclocked cards, like this MSI GTX 1650 Gaming X 4G, have higher clock speeds, and require a six-pin PEG connector.

The rumors on pricing ended up being a bit high. With a recommended price of $149 for the base models, the GTX 1650 is only slightly more expensive than a GTX 1050 Ti. Of course, there's still room for a $179 GTX 1650 Ti part, and this factory overclocked MSI model comes in at $180.

Nvidia claimed the GTX 1650 would be up to twice as fast as a GTX 950, and 50 percent faster than the GTX 1050, and that was probably a fair estimate, especially since both of those cards only have 2GB VRAM. Overall, the GTX 1650 lands right about where expected. It's faster than the GTX 1050, by 73 percent at 1080p ultra in our testing. Again, a lot of that is due to the 1050's limited VRAM, as the GTX 1050 Ti is much closer—the 1650 is about 30 percent faster. The GTX 1060 3GB leads by 9 percent at 1080p ultra, and the RX 570 4GB is in a similar position.

The GTX 970 is only slightly faster (1-3 percent) than the GTX 1650, mostly due to architecture improvements over the past two generations. Newer games tend to favor the GTX 1650, while older games are more likely to favor the GTX 970. In other words, a high-end 145W $330 card from 2014 has morphed into a budget 75W $150 card of today.

The difficulty with budget GPUs is that they never represent anything "new" in terms of performance. Yes, the GTX 1650 is faster than the previous-generation GTX 1050 Ti, but it's also roughly the same performance as a high-end GPU from nearly five years ago. Now that level of performance is available from a far less expensive 75W TDP card (give or take), and there will eventually be low-profile card models using the GTX 1650.

It could make sense as a cheap upgrade for an older PC, but it's not necessarily the best performance or value you can find right now. From a pure value proposition, especially with the discounted GTX 1060 cards still hanging around, along with AMD's RX 570 and 580, the GTX 1650 comes up short. Eventually, the stock of previous-generation GPUs will dry up, and the GTX 1650 will remain for a couple of years as Nvidia's budget offering, but that hasn't happened yet.

The GTX 1650 isn't a bad GPU by any means. It can hit 60fps at 1080p medium to high quality in most games, and it's affordable. Just make sure you understand what you're getting, because if you're looking at building a budget gaming PC, you'll almost always be better served by spending a bit more money. For a compact build or something that's only used for light to moderate gaming, the GTX 1650 is worth a look. But if you upgraded your graphics card any time in the past few years, you're probably doing fine. Can your card run the games you want to play? If it can't, it's fine to think about upgrading, but just because a card is several years old doesn't mean it needs to be replaced. **–JARRED WALTON**

VERDICT
7

MSI GTX 1650 Gaming X 4G

➕ **BUDGET** Over 50 percent faster than GTX 1050; no extra power required on many models; great for small builds.

➖ **FUDGED IT** Costs more than the GTX 1050; struggles in more demanding games; not the best value.

$180, www.msi.com

BENCHMARKS

	MSI GTX 1650 Gaming X 4G	Radeon RX 570
Tom Clancy's The Division 2 (Avg fps)	43	**55**
Deux Ex: Mankind Divided (Avg fps)	38	**44**
Far Cry 5 (Avg fps)	**67**	64
Grand Theft Auto 5 (Avg fps)	**45**	38
Middle Earth: Shadow of War (Avg fps)	38	**42**
Metro Exodus (Avg fps)	31	**35**
Total War: Warhammer II (Avg fps)	44	**46**

Best scores are in bold. Our test bed consists of an Intel Core i7-7800K, 16GB of G.Skill DDR4-3200, a Gigabyte Z370 Aorus Gaming 7, and a 1TB Samsung 970 Evo M.2 SSD. All games are tested at their highest graphical profile with AA turned on, at 1080p.

SPECIFICATIONS

GPU	Turing TU117
Lithography	TSMC 12nm FinFET
Transistor Count	4.7 billion
CUDA Cores	896
Texture Units	56
ROPs	32
Core/Boost Clock	1,485/1,860MHz
Memory Capacity & Type	4GB GDDR5
Memory Speed	8GT/s
Memory Bus	128-bit
TDP	75W
Display Connectors	1x HDMI 2.0b, 2x DisplayPort 1.4

Factory overclocked models, like this card, cost more than the base models.

Western Digital Black SN750 1TB

WD respins its high-performance NVMe drive

SOLID-STATE STORAGE isn't exactly a recent innovation, but it has arguably taken some of the better-established names in general PC storage to get a grip on the SSD market. Take Western Digital. Long a leading maker of conventional magnetic hard drives, its early SSD output was patchy.

Its first effort at an NVMe drive, for instance, was underwhelming. Admittedly, a second-generation model appeared last year with much improved performance, but with this third-gen drive, can Western Digital go all the way to the top of the table? On paper, the new WD Black SN750 looks pretty promising.

Like last year's update, the SN750 comes in M.2 format, has an in-house WD controller chipset, and utilizes 64-layer 3D TLC NAND flash memory. To that WD has added refined firmware and a model, tested here, aimed at enthusiasts and gamers, and fitted with a hefty heatsink. In terms of the claimed specifications, the 1TB model offers marginal increases in sequential performance. Reads are up from 3,400MB/s to 3,470MB/s, while writes step up a little more, from 2,800MB/s to 3,000MB/s.

Claimed 4K random performance is improved, too. Random reads increase from 500K IOPS to 515K, while writes increase from 400K to fully 560K. It's also worth noting that this 1TB version is the fastest of the new WD Black models across the board, including the 2TB drive. That's partly because the 2TB model uses 512Gb memory chips to the 1TB model's 256Gb chips.

Of course, with the passage of time since the previous drive, known as the SN700, arguably the biggest change is pricing. Back in April last year, the 1TB model clocked in at around $450. The improved 1TB model slots in at around $225, while the newly introduced 2TB option is only $50 pricier than the previous 1TB model at $499, albeit those prices are for bare drives, rather than those with heatsinks (this 1TB model is $250 with the heatsink). Whatever, some say that Moore's Law is dead, but they forgot to tell the SSD market, because drives keep getting cheaper. And dramatically so.

As for other tweaks, WD has cooked up a revised build of its SSD Dashboard app. Newly added is a Gaming Mode, which disables Autonomous Power State Transitions and, in turn, low-power idle states for more consistent response. The idea is to avoid the brief lag incurred in waking a drive up from sleep states, but at the cost of power consumption. Zero-watt power consumption has been a standout feature for the WD Black, but the marginal downsides of disabling lower power modes probably won't bother most desktop users, especially gamers.

If that's the speeds and feeds covered, how does the new SN750 actually perform? It's always interesting to note how well a drive with multi-level NAND cells performs once you burn through whatever single-level cache the manufacturer has apportioned. In this case, the answer in terms of internal file copying is a hefty 1GB. It'll keep on trucking at that speed for hundreds and hundreds of GB, which is impressive, so you can fill this drive to brimming in about 10 minutes. Not bad for a 1TB model.

As for more specific benchmark results, the SN750 puts in some very solid numbers. There are a few weak spots compared to the opposition, including QD1 random reads, but equally, there are some real highlights, such as QD1 random writes. Overall, WD's latest definitely deserves comparison with the best NAND-based drives, even if Intel's Optane SSDs retain a big advantage in terms of random access performance and latency, and it's not a huge step forward over last year's WD offerings. Then there's the overall package, including a five-year warranty and well-established power efficiency. The latter makes it a good choice for laptop implementations. For everyone else, it's just a solid all-around proposition. –**JEREMY LAIRD**

BENCHMARKS

	Western Digital Black SN750 1TB	Intel 905p 1.5TB	Samsung 970 Evo Plus 1TB
30GB Internal Copy (Seconds)	32	29	**24**
CrystalDisk 6 Sequential Read (MB/s)	3,479	2,632	**3,565**
CrystalDisk 6 Sequential Write (MB/s)	3,003	2,313	**3,342**
Anvil 4K QD 1 Read/Write (MB/s)	38/**213**	**131**/145	45/151
Anvil 4K QD 2 Read/Write (MB/s)	75/**340**	**245**/273	96/299
Anvil 4K QD 4 Read/Write (MB/s)	124/692	**468**/518	191/**735**

Best scores are in bold. Our test bench consists of an Intel Core i7-8700K, an Asus Maximus X Hero, an Nvidia GeForce GTX 1080, 16GB of Corsair Dominator Platinum DDR4, and a Samsung 850 Evo 250GB OS SSD.

VERDICT
8

Western Digital Black SN750 1TB

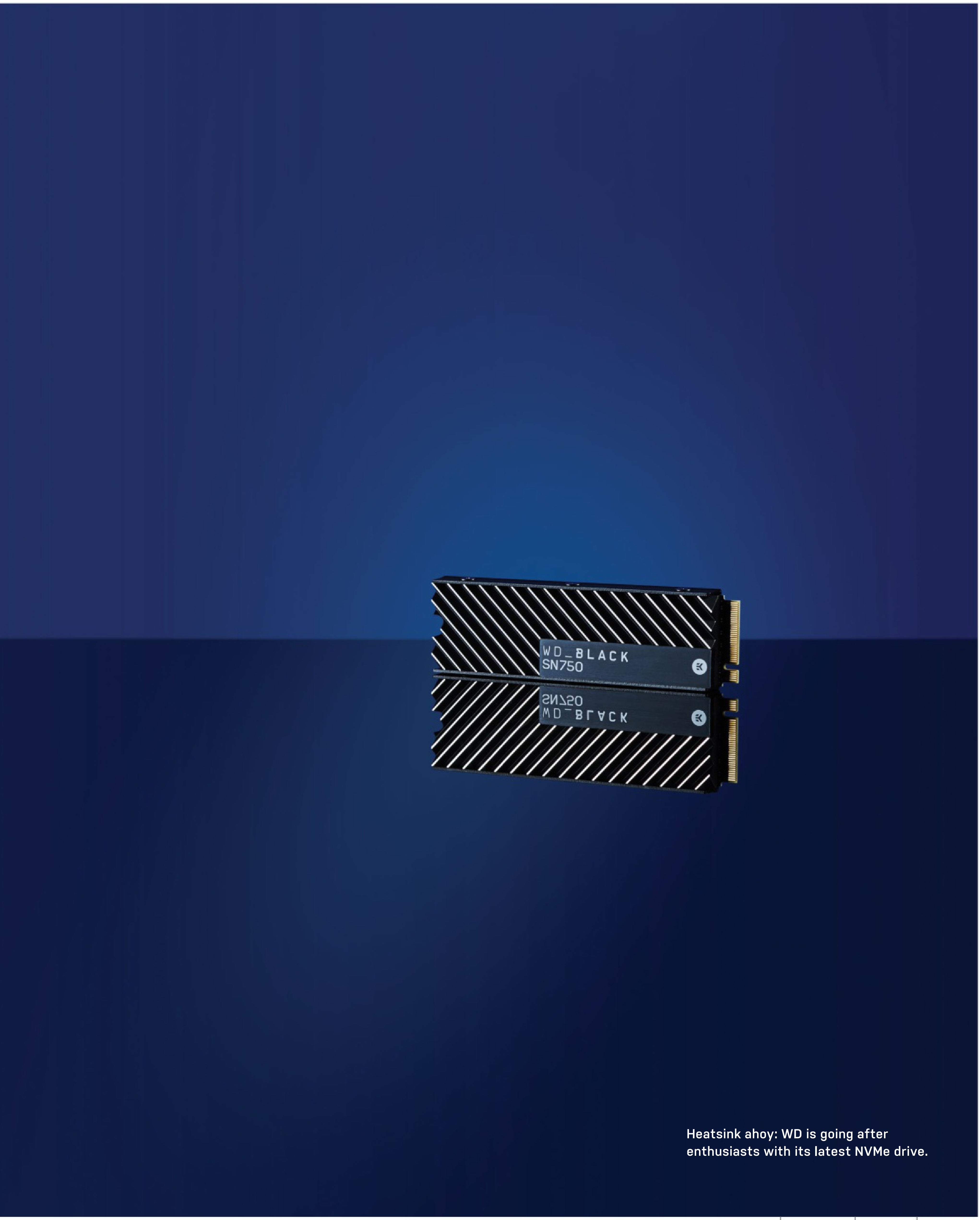
➕ **SOLID** Strong all-around performance and features; good warranty.

➖ **WHAT A STATE!** Not a huge step up from WD's previous NVMe drive.

$250, www.wd.com

SPECIFICATIONS

Capacity	1TB
Interface	PCIe x4
Control Protocol	NVMe
Controller	Western Digital
NAND Type	64-layer TLC
Sequential Read	3,400MB/s
Sequential Write	3,000MB/s
Read IOPS	515K
Write IOPS	560K
Warranty	Five years


WD_BLACK
SN750

Heatsink ahoy: WD is going after enthusiasts with its latest NVMe drive.

ViewSonic
ELITE

ViewSonic's new 24-inch gaming panel features 144Hz refresh and RGB lighting.

ViewSonic Elite XG240R

Great for gaming, but at a cost...

HOW MUCH ARE you willing to sacrifice for the best possible gaming experience? Resolution? Viewing angles? Stick both on the list, along with color accuracy—they're all going to take a hit if you go for the new ViewSonic Elite XG240R.

That's not necessarily a problem. The XG240R is nothing if not unapologetic. It's all about gaming. And not just any old gaming, but specifically esports. Consequently, its 24-inch LCD not only uses TN as opposed to IPS or VA panel tech, but it sports a mere 1920x1080 native res. But factor the sub-$300 price into the gaming remit, and those are positive choices rather than compromises.

The TN tech makes for fast responses; ViewSonic rates the XG240R good for 1ms with overdrive enabled. As ever, claimed pixel response specs are best treated with a healthy skepticism, but it is indicative of a quick panel. The better to support the pacey 144Hz refresh rate. Similarly, the mere 1080p native resolution is a good fit for a gaming monitor at this price. It minimizes the load on the graphics subsystem, enabling higher in-game frame rates.

There are also plenty of extras to sweeten the deal. First up is Elite RGB, which involves a pair of RGB lighting zones on the rear of the panel enclosure. They're compatible with the RGB lighting in peripherals from the likes of Razer, Thermaltake, and Cooler Master, so you can sync the whole shebang together in a unified lighting show, if that's your thing.

There's also a low input lag mode and AMD FreeSync support. Regarding the latter, the XG240R hasn't made Nvidia's preferred list of G-Sync compatible monitors, so you'll have to force G-Sync on with Nvidia graphics cards.

On paper, it's a promising package. And so it mostly proves in practice. Subjective response is excellent, and the 144Hz does what it says it does. This is a very quick and responsive gaming panel. Our main reservation from a gaming perspective is the extent to which some of the image adjustment options are tied to presets—it would be nice to be able to adjust the pixel overdrive setting, regardless of preset.

Move away from gaming, and the results are more mixed. For a TN panel, the colors are actually pretty punchy, but there's no disguising those limited TN viewing angles. Some compression is visible in brighter tones, too, and overall contrast levels are simply not on a par with more expensive panel technologies.

Arguably more of an issue for general duties is the 1080p native resolution. If you're accustomed to 1440p or 4K, 1920x1080 feels constraining. Likewise, that resolution on a 24-inch display works out to a fairly tragic 92 ppi. Not exactly the stuff of precision-rendered fonts. The integrated speakers are also the most feeble by far we have ever encountered.

But do the pathetic speakers, fat pixel pitch, and mediocre viewing angles matter, given the gaming remit? If you want a gaming monitor that combines a high-quality IPS panel with 144Hz-plus refresh, you'd have to pay far more. For us, this ViewSonic gives up too much in general computing terms. For the money, you can have far more and higher quality pixels, and even a larger panel. This is low-end 4K territory. We'd trade the high refresh and low response times for that. But if you're a single-minded gamer on a fairly tight budget, the XG240R is worthy of a spot on your shortlist. **–JEREMY LAIRD**

VERDICT

7

ViewSonic Elite XG240R

+ THE GAME'S AFOOT Quick panel; fast refresh; lots of gaming-friendly features.

− GAME OVER Limited native resolution; mediocre image quality.

$260, www.viewsonic.com

SPECIFICATIONS

Panel Size	24 inches
Native Resolution	1920x1080
Pixel Density	92 ppi
Panel Type	TN
Maximum Refresh	144Hz
Response	1ms
Contrast	1,000:1
Display Inputs	DisplayPort, 2x HDMI
Connectivity	2x USB 3.0
VESA Mount	100 x 100mm
Warranty	Three years

PNY CS900 480GB

A TLC SSD for QLC money? There must be a catch…

SOLID STATE STORAGE prices have dropped off a cliff. We're now talking sub-$100 for a 1TB drive, and below $50 for 500GB. That's not far off half the price drives were going for six months ago. Insane.

Or it would be if such drives were easy to recommend. Often, they're not. Broadly speaking, entry-level SSDs fall into two categories. First are drives based on TLC NAND memory from brands you've never heard of. Rolling the dice on one of those is an unnerving experience.

The other option is a QLC drive from a more reassuring manufacturer. Problem is, the underlying performance of QLC NAND memory is garbage. Given all such drives operate with some level of SLC cache, one can debate how often the true performance of the bulk of the drive will be exposed. But it's certainly off-putting.

With all that preamble processed, this PNY drive actually looks pretty appealing. At $69 for this 480GB model, it's not the cheapest, but it is competitive. More to the point, PNY isn't some obscure outfit cranking out lashed-up drives thrown together from factory floor sweepings. Oh, and it's based on TLC NAND, rather than that QLC gunk. Result.

In that context, the fact that the CS900 brand originally came out a few years ago probably doesn't matter. On paper, it certainly looks promising. What's not to like about 550MB/s reads and 500MB/s writes from a SATA SSD?

Indeed, many of our benchmark results look quite acceptable. Granted, the CS900's 367MB/s sequential write performance is well down on PNY's claims, but it's just fine for a budget SATA drive. Random access 4K performance looks decent, too. By decent we mean orders of magnitude better than a mechanical hard drive.

However, the wheels fall off this particular train in our real-world 30GB internal file copy benchmark. Not far off five minutes is tragic. Moreover, it quickly became obvious that this drive can't sustainably deliver on PNY's claimed performance figures during our pre-test drive prep routine. The CS900 can only maintain its peak sequential performance for a few seconds before dropping down to a lowly 50MB/s.

Funnily enough, that's reminiscent of all the QLC SSDs we've tested, albeit those drives sustain their peak performance for longer before falling back to the inherent throughput attainable by QLC NAND cells. As for the whys and wherefores, part of the explanation is that the CS900 is a DRAM-less drive. Instead of inserting a DRAM cache between the controller and the NAND, the CS900 can only rely on 32MB of SRAM built into its Phison S11 controller chip.

Speaking of DRAM-less SSD controllers, it's worth noting that such implementations also raise question marks about drive longevity. A DRAM cache doesn't just boost performance; it also dramatically reduces wear on the flash cells. To PNY's credit, the CS900 is backed by a reassuring three-year warranty, which is all you can ask for at this price point. But even if PNY is fully co-operative in the event of a failure, you still have the possibility of significant downtime and data loss.

As promising as the CS900 looks on paper, then, the reality sails straight past underwhelming and right into avoid at your peril territory. Our advice? If you must go uber cheap, a premium brand QLC drive is the preferred option. Better yet, spend a bit more. **–JEREMY LAIRD**

VERDICT 4

PNY CS900 480GB

⊞ **WEALTH OF NATIONS** It's a big old TLC drive for not a lot of money; three-year warranty.

⊟ **BURGERNOMICS** Awful real-world performance; DRAM-less technology a worry for longevity.

$69, www.pny.com

BENCHMARKS

	PNY CS900 480GB	Samsung 860 Evo 500GB	Crucial BX500 120GB
30GB Internal Copy (Seconds)	280	**89**	224
CrystalDisk 6 Sequential Read (MB/s)	552	**563**	561
CrystalDisk 6 Sequential Write (MB/s)	367	**533**	238
Anvil 4K QD 1 Read/Write (MB/s)	28/87	**50/119**	31/112
Anvil 4K QD 2 Read/Write (MB/s)	42/139	**98/225**	53/197
Anvil 4K QD 4 Read/Write (MB/s)	91/214	**182/314**	87/207

Best scores are in bold. Our test bench consists of an Intel Core i7-8700K, an Asus Maximus X Hero, an Nvidia GeForce GTX 1080, 16GB of Corsair Dominator Platinum DDR4, and a Samsung 850 Evo 250GB OS SSD.

SPECIFICATIONS

Format	2.5-inch
Interface	SATA
Control Protocol	AHCI
Controller	Phison S11
Capacity	480GB
Memory Type	3D TLC NAND
Cache Memory	32MB SRAM (integrated)
Sequential Read Speed	550MB/s
Sequential Write Speed	500MB/s
Warranty	Three years

Cooler Master MasterKeys MK850

Features, features, and more features

LET'S START WITH a question: Are analog keyboards an intrinsically dumb idea? The answer could depend on how well trained your left hand has become at smashing WASD as hard as it can. Most of us have developed those fine motor skills in our thumbs, not our fingers, so approaching something like the Cooler Master MK850—which marks the commercial debut of Aimpad's long-gestating optical analog tech—might require a significant period of refactoring and readjustment. And not just when using the analog keys, because CM's decision to put mode-triggering M-keys up the left edge of the keyboard, just asking to be triggered by an errant pinkie or a mis-angled palm, is initially infuriating.

This isn't the first analog keyboard to arrive. We've done our share of gushing about the excellent Wooting One, and its full-sized sequel is due any minute. The MK850 is also not fully analog, saving its optical sensors for a patch of eight keys between Q and F. That's actually not a bad thing. While Wooting's whole board actuation height adjustment isn't present here, there's really no reason beyond that to have every key analog-enabled, and Aimpad's radical mix-up tech means Cooler Master has been able to use proper mechanical switches.

You don't get a choice of switch—it's Cherry MX Reds or the highway, son—but again, that's a logical move. The smooth travel, reasonable resistance, and high digital actuation point of the linear MX Red switches make them great for straight gaming and decent for typing, and also means they're suited perfectly to that analog double duty. It's central to Aimpad's take on the tech: The company's optical sensors gaze up at the base of commercial switches to check how far they've been depressed, in contrast to Wooting's combination of completely passive switches and an entirely optical mainboard. In theory, this might make it applicable to heavyweight Cherry MX Black switches (or, indeed, non-Cherry hardware), but it's unlikely to fit anything with a tactile bump—analog and linear feel like inseparable bedfellows.

KEY POINTS

Analog functionality is just the tip of the MK850 iceberg. There are two (two!) super-smooth knurled rollers on its jutting-out backside, alongside a row of dedicated media keys, and a pair of USB 3 pass-through ports behind, made possible by a slim braided USB Type-C cable. The slightly irritating M-keys access pre-configured analog modes, sidestepping the annoyance of applying said modes in software. On that point, there are three mysterious keys above the number pad, one that effectively reboots the keyboard, and two to tweak the analog actuation point on the fly.

If you don't want to use Cooler Master's Portal software, which is easy, functional, and stable, there's a cavalcade of customization options built in to the keyboard itself, from macro programming to RGB effects. While these are almost completely unfathomable without reading a manual (as is generally the case with Cooler Master keyboards), everything's stored on board, making this a perfect portable keyboard. The lighting itself is frankly stunning, with clear-based switches that play nicely with a handsome brushed aluminum top edge, more effects than anyone could possibly need, and a subtle light bar running along the front edge that you'll never see if you employ the magnetically attached soft PU leather wrist rest.

Even if you were to discount the option of using the eight analog keys, this would be a stupendous keyboard package. But those keys work well, and it's hard not to appreciate the fact that their stealthy presence doesn't make any portion of the keyboard feel even slightly different from the rest. They're not dumb—they're awesome. If only they didn't contribute to making this one of the most expensive stock mechanical keyboards on the market today, we wouldn't hesitate to recommend it. **–ALEX COX**

VERDICT
8

Cooler Master MasterKeys MK850

⊞ **ANALOG** Overflowing with features; beautiful lighting; neat analog tech.

⊟ **IN A BOG** Requires mental retraining; M-keys can be annoying; so expensive.

$199, www.coolermaster.com

SPECIFICATIONS

Switch Type	Cherry MX Red
Form Factor	Full-size
Media Keys	Yes
Macro Keys	Configurable
LEDs	Full per-key RGB
N-Key Rollover	Yes
Pass-Through	2x USB 3.0
Dimensions	18.7 x 6.1 x 1.7 inches
Warranty	Two years

HyperX Pulsefire FPS Pro

High-end mousing hidden in plain sight

MICE DON'T GENERALLY vary a huge amount from one to the other. There are buttons, there's probably a wheel, and a sensor underneath. Maybe there'll be some slightly advanced electronics controlling the sensor; perhaps there'll be some pretty lights. So, what do we, certified by our mothers as the world's pre-eminent mouse critics, do when a mouse comes along that checks all the boxes well enough—and even double-checks some of them—but elicits little more than a shrug under close examination?

That's what we have here, in the form of the overtitled HyperX Pulsefire FPS Pro. Nine syllables. There's no doubt its foundation comes from a good place: Kingston's gaming sub-brand rarely lets us down, and however dull it may be, plenty of effort has been put into the design and hardware of this mouse. It's a right-hander, but not to any sort of extreme, with a fairly narrow body that sees your pinkie and ring fingers sloughing off the right-hand side and touching the desk, and a shallow left-edge curve that doesn't make any assumptions about where you'd like to put your thumb. There are side buttons, kinda medium sized and bland—they each click with a very slightly different tone, and neither gets in the way or hides itself so well that it's impossible to find when you need it. Beneath those buttons, and on the opposite edge, is a slightly unpleasant-feeling diamond plate pattern molded into silicon, which is grippy enough without being sticky.

Up top, some RGB lights in all the usual places, one giving a glow to the HyperX logo on the heel, one highlighting the rim of the serviceable mouse wheel. There's a good amount of tension in the plain slate-gray one-piece top shell, enough to prevent the majority of accidental clicks, and it's shaped in such a way that it fits in your palm and fingers well, as mice so often are. Behind the wheel sits a single DPI switch, toggling between three resolution settings, which you can customize (along with the lighting) using Kingston's NGenuity software.

Underneath is even less exciting. We can appreciate not putting a huge amount of design effort into an area nobody's going to see, but there's not even the pretense of fanciness around the tiny sensor hole, although the slippery skates on either end are creditably large. Looking here does lead us to the Pulsefire FPS Pro's most remarkable feature: a Pixart 3389 sensor, which can be dialed all the way up to an unusably sensitive 16,000 dpi, and which predictably passed our mousing tests with flying colors. Probably the best sensor on the market today, and it's basically been hidden.

So, as we said, we struggled to find anything exciting about this mouse. It looks and feels like an amalgamation of every other mouse we've ever looked at, only slightly less remarkable than all of them. But perhaps that's what's so good about it. To answer that question posed at the beginning, to properly assess the FPS Pro, we need to look at what this is, rather than what it is not. All the drudgery of its standard features and plain outward design don't mean it's boring, as such, they mean this is a mouse made for mousing. There's nothing about it that's explicitly bad, and certainly nothing so wacky as to be distracting when you're in the middle of a firefight. It's comfortable enough, light enough, and every function is easily accessible; it's completely forgettable, in just the right way.

In fact, it's so dull we might even be tempted to recommend this over its hyperactive cousin, the Pulsefire Surge, which shares the same sensor, but adds a gaudy light ring and Omron switches certified for 50 million clicks, rather than the FPS Pro's 20 million. Considering that this is some $10 cheaper, and might just save you with its blandness, it must be pretty good after all. **–ALEX COX**

VERDICT
8

HyperX Pulsefire FPS Pro

+ **PLAIN** No-frills design; superb sensor at the price.

– **PAIN** Rough grips; thin braided cable.

$45, www.hyperxgaming.com

SPECIFICATIONS

Sensor	Optical
Sensitivity	16,000 cpi
Sensor Model	Pixart 3389
Polling Rate	1,000Hz
Programmable Buttons	6
LEDs	Two-zone RGB
Cable Length	5.9 feet
Weight	3.4oz

Fractal Design Define S2 Vision RGB

Taste the rainbow with a colorful case

IT'S A MOUTHFUL, isn't it? Fractal Design's Define S2 Vision RGB doesn't exactly have the snappiest name, but it's hard not to like it. This is an expensive case for true enthusiasts; the Swedish designer has poured its heart and soul into this one, and it feels like it. The Vision RGB feels almost like a love letter to those who like to array their rigs with LEDs. For an ATX case, it feels big and bulky—no surprise, given that most of the case is solid metal and tempered glass. It's sturdy as hell.

The large glass panels are affixed to the rear with thumbscrews, and it takes a bit more effort to get them loose even once the screws are removed, thanks to the pop-in clasps concealed beneath the black bezel. The upper glass panel pops loose with a push-pin release, though, and can easily be swapped out for an included plastic dust filter, on to which a radiator bracket can be connected. Inside, the motherboard cavity is spacious, with rubber-cushioned slots to feed cables through, and ample space for case fans. The Vision comes with four 140mm fans pre-installed, one at the rear and three at the front, and there's room for five more at the top and bottom. Look down and you'll spy a well-constructed PSU shroud at the base. Cleverly, this can double as mounting space for 2.5-inch SSDs.

Speaking of SSDs, let's take a trip around to the other side, looking at the rear of the motherboard panel: There are two dedicated SATA brackets, designed to be as unobtrusive as possible when not in use. There are also three sleek metal drive enclosures, stacked atop each other, with space in between to feed cables. Cable management isn't easy with this case—there's a few too many awkwardly tight spaces to shove your fingers into for our liking—but it rewards patience and care; if you're prepared to take the time to do it right, you could end up with an extremely tidy build.

In the center of the backplate sits the Nexus 9P PWM fan hub. The Vision RGB comes with a compact RGB controller in the accessories box, which can swap between multiple patterns and colors. It has to be tucked away in the rear, though, so you're probably best off downloading compatible RGB controller software.

Were we narrowed down to a single word, we'd describe the use of RGB in this case as "tasteful." A single LED lightstrip concealed along the upper metal frame, shining on the mobo, plus four of Fractal Design's Prisma AL-14 PWM fans, makes for a selection of synchronized lighting that impresses, but doesn't overwhelm. This is in part thanks to the muting effect the darkened glass has on the lights, making for a finished build that is sure to look colorful but not outrageous.

Remember how we mentioned it's expensive, though? Yes, this metal-and-glass obelisk may be solid and striking, but it checks in at $240—enough to make even a seasoned builder wince. There's a "blackout" variant that comes without the RGB elements for 40 dollars less, but even that isn't exactly what you could call cheap. The Vision RGB is an easy enough case to build in, with Fractal Design's trademark degree of organization and tidiness, but that's not enough to recommend it unilaterally. At the crux of it, this is a case that caters to those with building experience and money to spare. If you fit that bill, this could well be a worthy purchase. –CHRISTIAN GUYTON

VERDICT 8

Fractal Design Define S2 Vision RGB

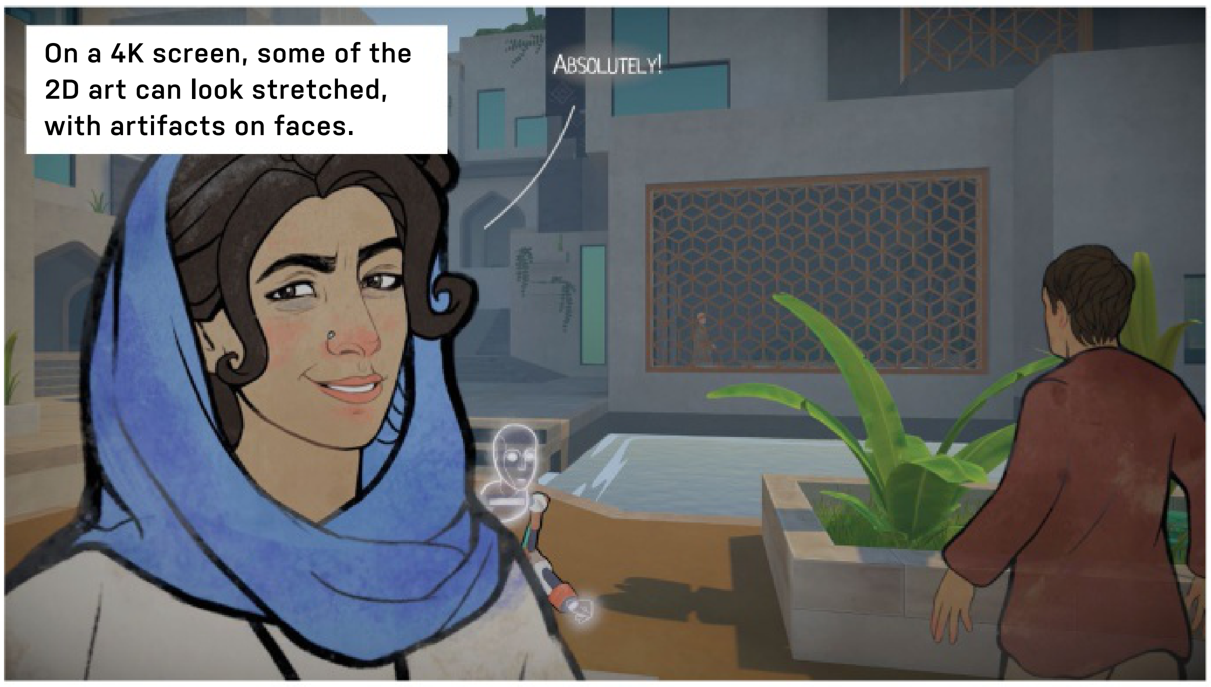
⊞ **LIGHTS** Sensible use of RGB; solid construction; elegant design; plenty of drive space.

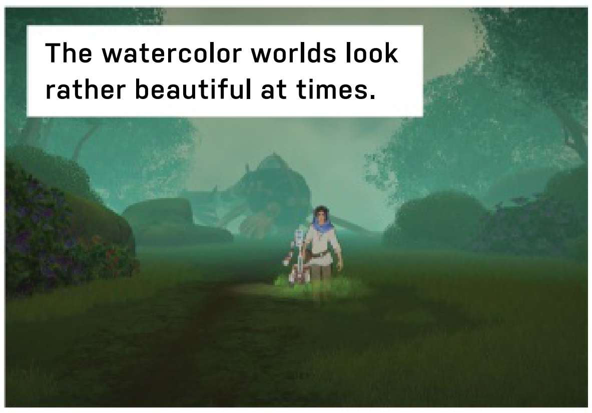
⊟ **FRIGHTS** High price point; complex cable management.

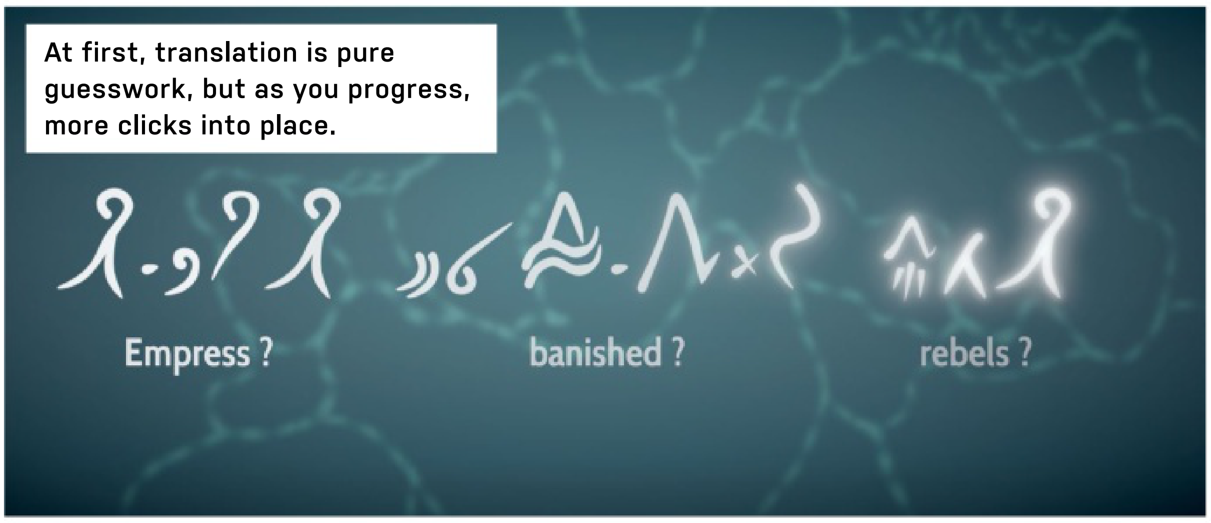
$240, www.fractal-design.com

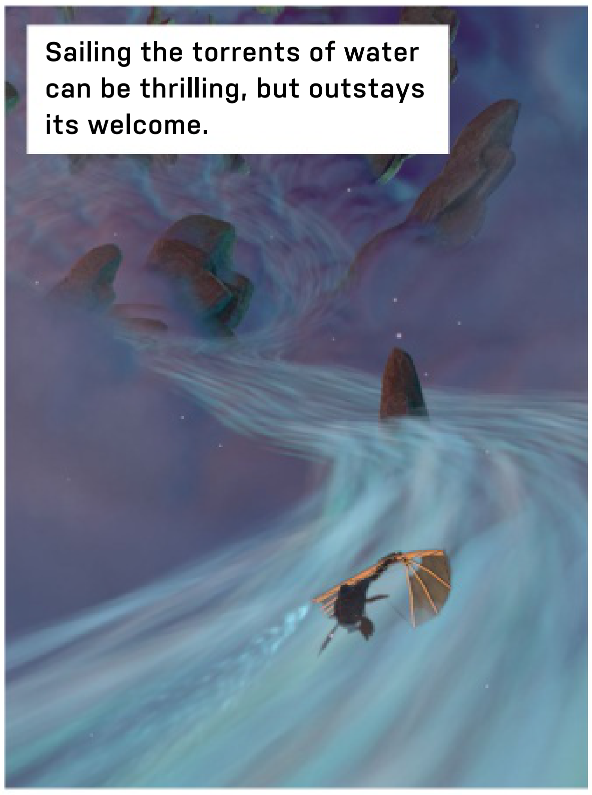
SPECIFICATIONS

Form Factor	Mid-tower
Motherboard Support	ATX, microATX, ITX
Colors Available	Black
Window Available	Yes
3.5-inch Support	3 (3 included)
2.5-inch Support	8 (5 included)
Radiator Support	360mm front, 360mm roof, 240mm base, 120mm rear
Fan Support	3x 140mm front, 3x 140mm roof, 2x 140mm base, 1x 140mm rear
Dimensions	18.3 x 9.2 x 21.4 inches
Graphics Card Clearance	017.3 inches
CPU Tower Clearance	7.2 inches
Weight	26.6lb


On a 4K screen, some of the 2D art can look stretched, with artifacts on faces.


The watercolor worlds look rather beautiful at times.


At first, translation is pure guesswork, but as you progress, more clicks into place.


Sailing the torrents of water can be thrilling, but outstays its welcome.

Heaven's Vault

Indie studio produces archeologist who's not Indy

A CREAKY SPACE sailing boat. An ancient language. A love of history. Giant stone feet. *Heaven's Vault* presents as a complicated mystery on first contact, and as story and game unfold, it does nothing to simplify itself—it's just a complicated mystery you understand slightly better.

A piece of interactive storytelling from Inkle, the studio behind the excellent cell phone game *80 Days*, *Heaven's Vault* casts you as an academic, an expert on history in a world that wants only science, on the hunt for a missing roboticist. You're also the only person who can figure out the meaning behind ancient writings no one else has bothered with, even though they may contain the secrets of humans' relationships with the robots they chip out of a concrete wall, rather than construct.

It will either distance you or intrigue you. The graphics too—simple in many ways, with a strange effect that leaves a ghost image every time you pause, and feet that merge into the ground—seem designed to elicit a second glance. Start playing, and the premise is intriguing enough to make you look past the rough edges, and when it's got your attention, it has remarkable sights to show you. A nebula in which water currents connect planets, moons, and rocks floating in space. Lush jungles, rice fields, and pig farms, a moon with no air left after a fire.... The combination of the mundane and the fantastic leaves you with no idea what you're going to encounter next.

Locations, reached by sailing those watery torrents with the aid of a chatty robot, often play out the same way. You reach an area, do some light investigating, and are presented with lines in an ancient language. You use guesswork and deduction to decipher what the symbols mean. A pictographic quality to them suggests one might be to do with water, another linked to the sky.

The game needs a better way of tracking these translations. An in-game notebook would do. Play for long enough, and unlock enough of its secrets, and the language starts to imprint itself on your brain, leaps of reasoning becoming more intuitive, and new translations coming faster. A speedy travel system between already visited places would be welcome, too, instead of having to return to the ship and the currents every time.

Inkle has produced a game of conversations and interpretations, wrapping a puzzle game in which you iterate your way toward the correct answer in the shell of an exploration game, and producing something greater out of the union. It's a game for a calm day, when you can devote enough time to it, its subtle reward, and the way it makes you feel clever, to be savored. –**IAN EVENDEN**

VERDICT 8

Heaven's Vault

+ HEAVEN Unusual mechanics; compelling plot; attractive looks.

– LEADEN Too much sailing; some ancient phrases actually quite difficult to crack.

RECOMMENDED SPECS Any CPU with SSE2 support; 4GB RAM; GTX660/Radeon HD 7850.

$25, www.inklestudios.com/heavensvault, ESRB: T

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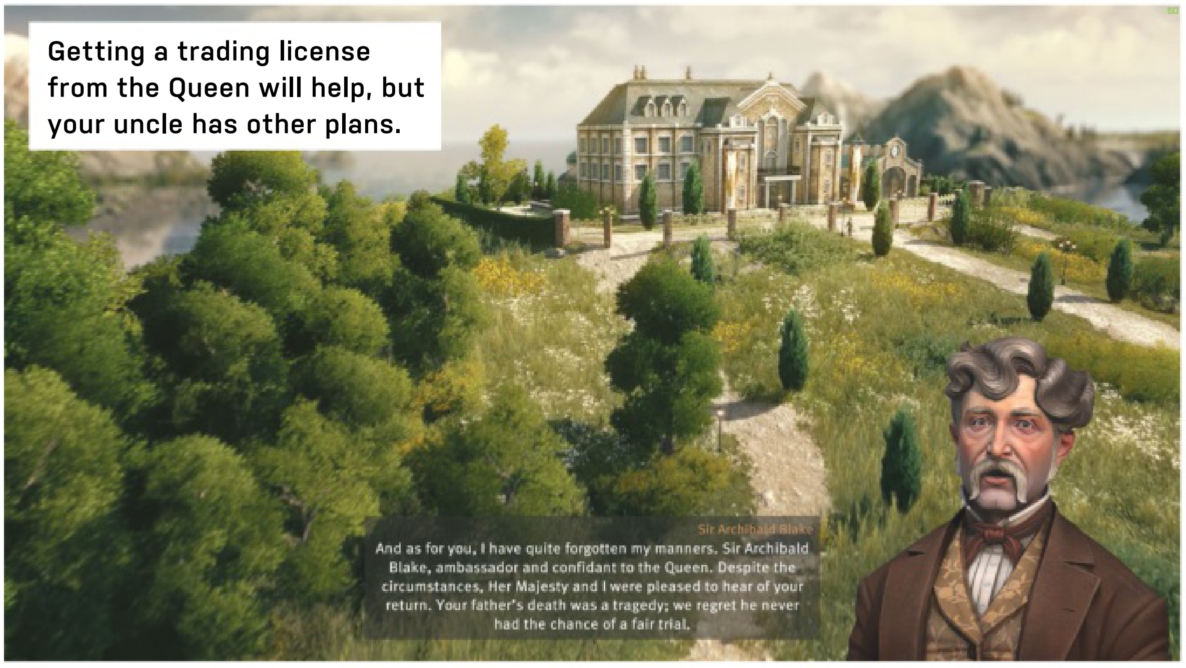
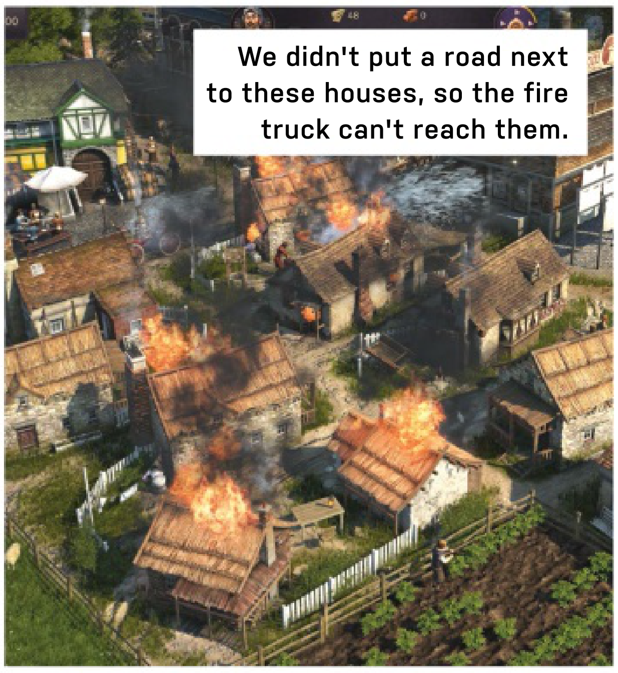
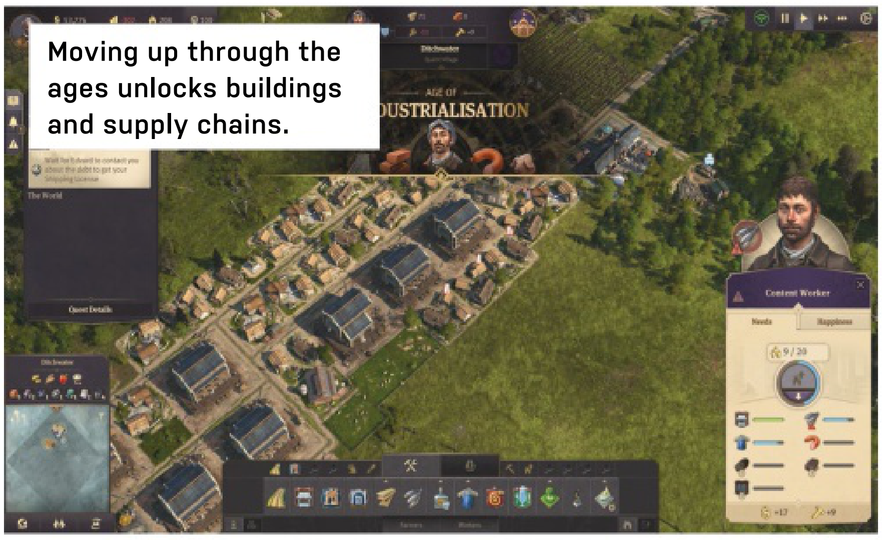


Getting a trading license from the Queen will help, but your uncle has other plans.

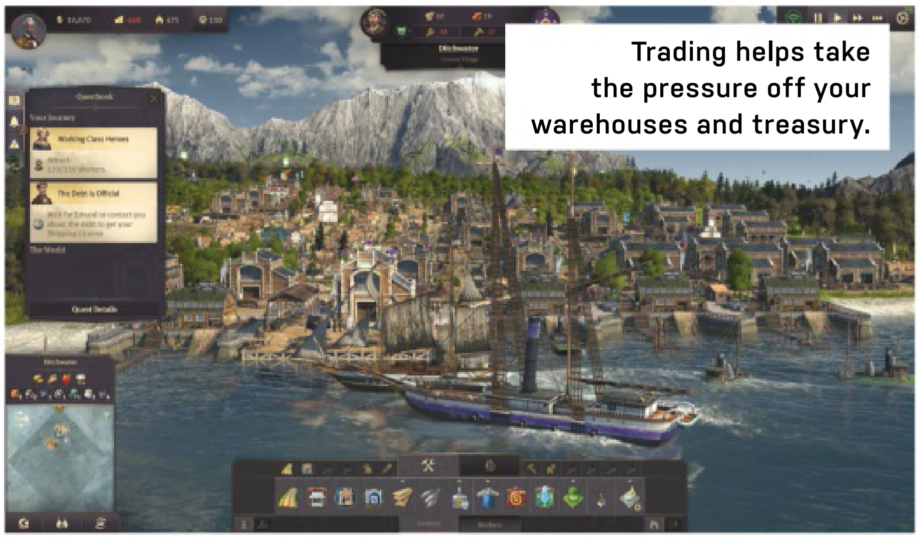
And as for you, I have quite forgotten my manners. Sir Archibald Blake, ambassador and confidant to the Queen. Despite the circumstances, Her Majesty and I were pleased to hear of your return. Your father's death was a tragedy; we regret he never had the chance of a fair trial.



We didn't put a road next to these houses, so the fire truck can't reach them.



Moving up through the ages unlocks buildings and supply chains.



Trading helps take the pressure off your warehouses and treasury.

Anno 1800

Island-hopping city builder just wants to get drunk

THE CITY-BUILDING GAME is surely due a renaissance, so it's pleasing to see Ubisoft give it an industrial revolution, too.

As the eldest child of a beloved island-city magnate, your job should be to pick up where he left off. However, your scheming uncle takes over, and charges you for your father's funeral, so you leave to start anew, on a nearby uncolonized island. Eventually, you attract workers, build a thriving civilization, complete the campaign, and seamlessly enter a sandbox mode to which there is no end.

This new *Anno* is ridiculously complex, with each layer of systems you unlock hinting at more to come. Early sheep farms allow you to position fields individually. When you unlock zoos, you build individual enclosures for animals. Early drafts of cities are thrown out, buildings are upgraded, moved, or demolished, diplomacy and trade engaged in, the raw materials for rum tracked down, and wars fought. It's mentally exhausting.

It all rattles along at a serious pace, with the game aware enough of players' tendency toward tunnel vision that it reminds you when you've been playing for two hours straight, and tells you to go get a coffee. There are other announcements, too, such as the clipped British accent that informs you of every autosave. Voices are one of the game's high points, and some charming phrases crop up, with a farmer being "as happy as a frog on a lily pad."

That's assuming your population is happy. There's plenty that can make them discontented, from poor working conditions to pollution. It's often nothing the deployment of a seedy drinking den can't sort out, but as your farmers become workers and ascend the social scale, their needs become more sophisticated.

Upgrading your population from farmers to workers to engineers and beyond is the way to unlock new buildings, but you need to keep the lower classes around to staff the fisheries and sheep farms. An upgrade comes when you have enough citizens of the previous level, constantly pushing you to increase the population. Increase too rapidly, however, and you risk bankruptcy, as the upkeep of all your new buildings outstrips their initial productivity.

Rebooting *Anno* for the 1800s has resulted in a game that's as rich and deep as the soil you grow your potatoes in. And just like the schnapps production line this triggers, it only takes a moment of inattention to see terrible shortages and riots in the street. The message that good mayors keep their populations merrily drunk is one we can certainly get behind. **–IAN EVENDEN**

VERDICT

7

Anno 1800

+ SCREWDRIVER Beautiful; amusing voice lines; realistic concentration on alcohol supply chains.

− OLD-FASHIONED Enormous time sink; comedy moments can grate; moving beyond 1080p and High settings needs serious gear.

RECOMMENDED SPECS i5 4690K/Ryzen 5 1500X; 8GB RAM; GTX 970/R9 290X.

$60, www.ubisoft.com, ESRB: T

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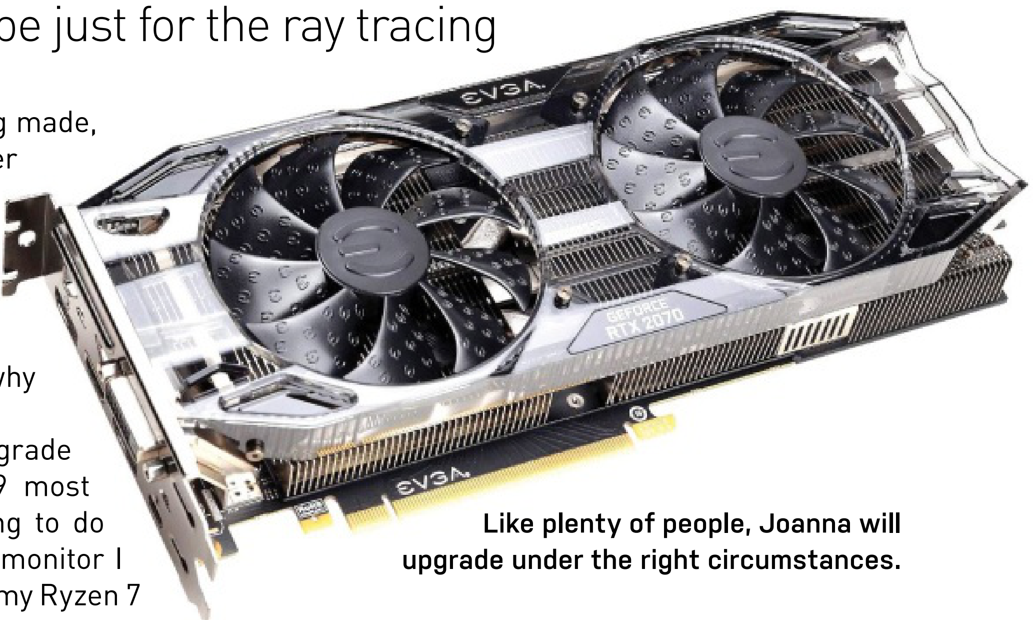
LAB NOTES

JOANNA NELIUS, HARDWARE STAFF WRITER

I'll Get an RTX GPU—Eventually

And honestly, it will be just for the ray tracing



Like plenty of people, Joanna will upgrade under the right circumstances.

RAY TRACING IS ALREADY influencing the future of hardware and game development, in both the PC and the console sphere. The next version of the PlayStation could use a scaled-down version of a Navi 20 GPU, which supports ray tracing. The list of ray tracing-compatible games is slowly growing, and higher resolution monitors make them look even more beautiful—if you don't mind the performance hit.

But even though ray tracing is the current driving force in tech, I'm still happily attached to my GTX 1080 Ti for many reasons, none of which is surprising. I could have bought an RTX card when I built my rig a few months ago, but aside from spending hundreds of extra dollars, the GTX 1080 Ti is not all that different performance-wise from the RTX 2070. Sure, the 1080 Ti is last-gen hardware and no longer being made, but I get way over 60fps at 1080p on ultra. I've also yet to be convinced to upgrade to a higher-resolution screen, so tell me why I need an RTX card.

I don't, but I'll upgrade at the end of 2019 most likely. It has nothing to do with price or what monitor I have, or upgrading my Ryzen 7 2700X to one of the Ryzen 3000 CPUs for that extra boost in processing power. (I'm a Ryzen fangirl, through and through.) It's the future release of two games that will make me upgrade: *Atomic Heart* and *Vampire: The Masquerade—Bloodlines 2*. Both are ray tracing-compatible, and even if they weren't, they are still the two games I'm most looking forward to playing in the next year. I'm willing to upgrade my GPU just for those games because I'm that excited for them.

ALAN DEXTER

Executive Editor

Most of the gear we use in our test rigs is not ours—we have to return it to the manufacturer at a moment's notice. Something that recently happened with the ViewSonic VP3268-4K, a screen I've been using since the start of the year. Of all the gear I've used of late, giving this up has been the hardest. Far harder than any high-end graphics card, CPU, silly amount of RAM, VR gear, or anything. Once you've used a quality 4K display, nothing else matches up, whether it's an affordable 4K TN panel, quality 1440p IPS screen, or high-refresh gaming panel. I've tried a number of screens since losing the ViewSonic, but nothing's managed to push it from my memory.

JARRED WALTON

Senior Editor

AMD is set to launch new 7nm Ryzen CPUs and Navi GPUs at Computex and E3, and I'm super-stoked to see how they perform. The third-gen Ryzen CPUs have a legitimate shot at claiming the overall performance crown from Intel for the first time in over a decade, but I'm less sure about Navi. The process shrink and new architecture should close the gap with Nvidia, but if AMD sticks with its historical approach, mid-range and budget GPUs will come first. Hopefully, AMD surprises everyone and releases a killer ray-tracing solution that beats Nvidia—or just skips ray tracing for now and gives us RTX 2070 performance for half the price. I could live with that.

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Editors' Picks:
Digital Discoveries

Hardware lead, Bo Moore, and staff writer, Christian Guyton, enjoy the fruits of developers' labors

OCULUS RIFT S

I've never been a huge fan of VR. I tried a few of the early iterations of the Oculus Rift, and wasn't too impressed. Of course, the experience has gotten much better over the years. My problem now is that for high-end VR experiences—with both hand and head tracking—you need a complicated setup involving one or more sensors mounted around your room (not to mention ample obstacle-free play area). At least, until now.

I've spent some time testing the Rift S, the new flagship VR product from Oculus. Replacing the classic Rift in Oculus's product suite, the Rift S offers full head and hand tracking without any external sensors. Instead of having to mount base station cameras around the room, the Rift S uses inside-out tracking via a handful of sensors positioned on the headset itself.

The result is a VR experience akin to the previous gold standard, but without the hassle of external sensors. Even just dinking around in the demo games my unit came with, I was impressed with the way VR has evolved. Is it ready to replace traditional gaming yet? Not at all. But VR has come a long way, and will continue to grow as more developers embrace it.

$399, www.oculus.com

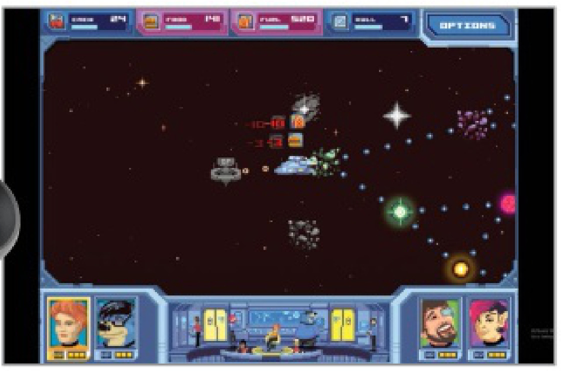
JUMP

I'm still feeling the effects of the game-streaming feature from the last issue. Thanks, Google. On the bright side, my research left me in touch with a number of contacts for gaming platforms such as Shadow and Utomik. One that has stuck with me is Jump, a service that downloads games to your PC piecemeal, enabling near-instant access to a strongly curated library of indie titles.

A good variety of games is key to a service like this, and the Jump team has got variety in spades. From fast-paced action to ponderous, story-driven adventures, it wasn't hard to tally up a list of games for me to work through.

Two games that particularly hooked me were *Orion Trail* and *Diaries of a Spaceport Janitor*. The former is a punishing pixel-art jaunt through a weird and wonderful galaxy fraught with random encounters, pop-culture references, and expendable red-shirted crew members, blending text adventure with resource management sim. The latter is an oddly meditative gem; I played a down-on-her-luck alien as she worked her government-subsidized garbage collection job, exploring a sprawling technicolor spaceport.

$5 per month, www.playonjump.com



GEEK TESTED & APPROVED

Anker PowerWave 15 Wireless Charger

WIRELESS CHARGERS aren't new, but that's a good thing; they've been around long enough for manufacturers to start perfecting them. Anker is one such manufacturer, and its newest version is as slick as they come. A solid metal base gives this charging pad some serious heft, and the top is banded with four raised rubber corners to protect your phone from scratches and stop it moving around while it charges. A cool blue light sits on the front of the unit, illuminating while a device is charging.

Thanks to its 15W capacity and power delivery via USB-C, Anker's charger is a great addition to any setup. Its proprietary PowerWave tech ensures faster charge times than most, and it can charge any Qi-compatible product up to the maximum wattage it can receive. Anker also sells an adapter for wall plugs that enables fast charge modes on compatible phones, be they Android or iPhone.

The stock cable is a USB 3.0 Type-A connector providing charge to a USB-C output, which can be unplugged from the pad to provide direct charging or data transfer. If you'd prefer a longer cable, it's easy to upgrade. The cable that comes in the box has a high-quality fabric sheath, ensuring better resistance to wear and tear.

Another nifty feature is the ability to charge through soft materials up to 5mm thick. This means that cases (even thicker ones such as Otterbox cases) don't need to be removed for charging, a common stumbling block for many wireless chargers. Just don't use a metal case—this will trigger the built-in foreign object detection, and interrupt charging. **–CG**

$36, www.anker.com

LETTERS

WE TACKLE TOUGH READER QUESTIONS ON…

> Buying on a Budget
> Duplicate Photos
> Dream Builder

Budget Buyer

I have just read your December 2018 issue that gives information about building a PC for $285. Can you tell me where I can get this kit? **–Rick Khona**

EXECUTIVE EDITOR, ALAN DEXTER, RESPONDS: We don't give specific sources for such builds, as they're intended to be reasonably evergreen, thus we assume you'll shop around to find the best deals at any specific time, or you'll tailor the build to your needs. A good way of tracking down prices and availability is to use the PC Part Picker website (www.pcpartpicker.com), which scrapes together the best deals for your build. Obviously, you'll see some movement on the price of this machine at any particular time, and price shifts at this end of the market can be more marked than on more powerful builds. Even so, we've just typed in the build using the site, and the overall price rolled in at $278, which is pretty impressive—although we did have to enter the price of the case manually, as it wasn't picking it up from Newegg, even though it was available from there.

Find and Replace

This is in response to F. Ewing asking readers what duplication finder apps they use in the letters section of the May 2019 issue. I like Awesome Duplicate Photo Finder, because it shows both photos, then lets you delete one. It can be a time-consuming process, but this makes it easier. Available from www.duplicate-finder.com. **–Edmund Shaw**

Dream Machine

Main motherboard dead: broken memory socket and bent pins? I thought a *Maximum PC* cardinal rule was to bench test the motherboard before installing it in the case. I always use a magnifying glass to detect bent pins—it saves a lot of character-building later. The dead memory socket would be moot, as you would have returned the board pronto. When the BIOS comes up, you can usually conclude the board is OK. I am a little fuzzy how you installed two power supplies to have access to the power switches. Great Dream Machine build. **–Ron Apra**

EXECUTIVE EDITOR, ALAN DEXTER, RESPONDS: Testing the motherboard before a build is a rule for some of us, but for others it's little more than a recommendation. Zak built this year's Dream Machine, and while he doesn't see such testing as essential, to be fair to him, there were some serious time pressures, compounded by the fact that components were still turning up after the photo shoot had started (and a photo studio isn't necessarily the best place to test out gear). So, yes, please test motherboards (and other hardware) before you start your build, but we won't hold it against you if you don't have time.

Not Playing

In your October 2018 column, you said it was a great time to build your own PC. My 12-year-old Dell Inspiron is about to give up the ghost. I do not want a game machine, and am frustrated that your magazine appears to ignore those of us who are not interested in the top end of gaming PCs. I've subscribed for almost three years, hoping your magazine would have at least one small article on how to build a great budget machine for home use. I use mine for a very small business and web surfing.

I desperately want to build a very fast machine with the latest, best hardware, and keep the price well under a thousand dollars. I know it can be done. I am about to break down and go ahead and build your October "$601 full HD gaming beast." I don't need water cooling or any of the requirements of a gaming machine. I could save money and maybe use the cash for a better and faster computer that is not geared for games. Maybe I don't need anything better. I just want a fast boot and quick speed. I'm frustrated.

Any advice? As far as I know, I want 8GB of RAM, a 500GB SSD, multiple cores, but not so many I can't use them (I have two cores now and want at least a quad to speed up startup and multitasking). You would know what else I need, and

↘ submit your questions to: comments@maximumpc.com

especially what I don't. I am ready to build it now.
–Terry Lippold

EXECUTIVE EDITOR, ALAN DEXTER, RESPONDS: There's a bit of a focus from the industry in general toward high-end gaming systems, because that's where a lot of the money and advances are, but if you aren't interested in gaming at all, we have some good news: Just take the graphics card out of the parts list, and make sure that the CPU has integrated graphics, and build as normal (minus the graphics card stuff). The power requirements of such a machine will be lower as well, so you could drop to a lower-powered PSU. We have a few builds lined up that don't use graphics cards in the next few months, so keep watching this space. If you're eager to get building, your base system seems reasonable, though we'd be tempted to up the memory to 16GB, and go for either an AMD Ryzen 7 2600 or Intel Core i5-9400, and build accordingly.

Unwanted Guests

I recently had two public agencies install hard-to-remove programs on my PC. The first was the Post Office: I downloaded the app it supplied in order to track a mailing. Its tracking app infected my browser (Firefox) so that from then on, if I searched online, the first thing that came up was the tracking app. I found this difficult to remove, and got rid of it by returning to a backup I'd done a few days before. The next instance was using the app for the Seattle bus schedules. Again, from then on, the first thing I saw whenever I opened my browser was a page for bus schedules. I got rid of this by installing the Norton interface for my browser.

First, there should be a straightforward way to remove unwanted apps like these. Second, what right do these agencies think they have to do this?
–Robert Whitley

EXECUTIVE EDITOR, ALAN DEXTER, RESPONDS: No website should do this. No company, government body, individual, or anything else should hijack your browser in this way—indeed, this is what it's called: a browser hijack. This can take many forms, from installing browser extensions that intercept your normal search activity to redirecting your homepage to that of the site instead (in some cases, this could lead to your browser of choice being replaced with another, although under Windows 10, you're alerted, and have to agree to such activity).

Undoing such a hijack can range from easy to complicated, depending on how it's been achieved. You can reset Firefox to its default settings by clicking the "hamburger" menu button, selecting the question mark from the drop-down menu, selecting "Troubleshooting information," then hitting "Refresh or Reset Firefox." If you've got additional toolbars that aren't shifting, you should be able to uninstall these from the "Extensions" menu under the "Add-ons Manager."

Audio Clarity

I was grateful to see Tom Woroby's response regarding soundcards. I decided to give his suggestion a try, and bought the Asus Essence STX II soundcard. The only thing I have to say is: It's great. To my ears, there is a distinct improvement in overall sound quality compared to the motherboard sound. The software included has a multitude of variables to play with, but as I wish the sound to come out without any effects added, I did not use them. The songs I'd written and mixed already have effects, so I needed the cleanest reproduction of that sound, and this card does that. It seems to be a big step up in quality from the sound on the motherboard, both through headphones and my JBL studio monitors. I realize sound and music are a subjective area, but for me, Tom's suggestion hit the nail on the head. The way I look at it, if it suits your ears, use it, be it motherboard or soundcard. So, I wanted to thank Tom Woroby for his suggestion, and the *Maximum PC* editors for providing a great forum for discussion and ideas to enhance our experiences with our PCs.
–Rick Breckwoldt

[NOW ONLINE]

RAGE 2 SYSTEM SPECS, BENCHMARKS, AND PERFORMANCE ANALYSIS

© BETHESDA

Rage 2 is out, delivering fast-paced run-and-gun action with vehicular combat. We're here to talk about performance, and there's plenty to cover. We've tested *Rage 2* on our usual suite of graphics cards and CPUs—26 GPUs and 8 CPUs, to be precise. We also discuss system requirements, all the settings, and other major features.

Rage 2 can run well on mid-range hardware, but budget GPUs in particular are going to struggle. We wouldn't plan on maximum image quality at 1080p unless you have at least a GTX 1070 or better. For budget cards, such as a GTX 1050 or RX 560 (or older GTX 760 and R9 370), you'll probably want to drop the resolution or use resolution scaling to stay closer to 60fps.

Read the full article: https://bit.ly/2HqVcke

EXECUTIVE EDITOR, ALAN DEXTER, RESPONDS: If you'll excuse the terrible pun, it's good to hear that you're happy with your audio upgrade.

Fan Orientation

Can we get a "how to" on fan directions? I see so many different setups—is there a proper way? All blowing in, out, some in, some out…. Have any tests been done? **–Dusty Miller**

EXECUTIVE EDITOR, ALAN DEXTER, RESPONDS: We've covered this a little in this month's system building cover feature, so read that for the low-down, but the orientation of your fans generally doesn't make a huge difference to cooling. How you have them set up does affect the amount of dust you introduce to your machine, though, which ultimately affects cooling. Positive pressure is generally considered the best way to keep dust out.

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THE BUILDS

BUDGET

INGREDIENTS

PART			PRICE
Case	BitFenix Nova TG		$55
PSU	450W EVGA 450 BR 80+ Bronze	**NEW**	$35
Mobo	ASRock B450M R4.0 AM4		$65
CPU	AMD Ryzen 5 2600		$155
GPU	Gigabyte GeForce GTX 1660 6GB		$220
RAM	8GB (2x 4GB) Patriot Viper 4 @ 3,000MT/s	**NEW**	$45
SSD	120GB Crucial BX500 2.5-inch SSD		$20
HDD	1TB Seagate Constellation ES 3.5-inch HDD		$36
OS	Ubuntu Desktop Linux 18.04 LTS 64-bit		$15

Approximate Price: $646

CHANGES? This isn't a David Bowie track. The only thing we saw fit to trade out this month was the power supply and the RAM, and these were only minor changes. Power-wise, there was no need to step above 450W, but despite PSU prices still sitting quite high, we were lucky enough to spy EVGA's 450 BR, trading out the previous Corsair PSU to save ourselves five dollars. We turned that five into a ten by exchanging the 2x 4GB T-Force Vulcan memory for Patriot's Viper 4 kit of the same size and frequency. The timings and CAS latency on these two kits are identical, so any functional performance changes will be extremely minimal. Those aren't the only savings we made here, though; the price of the Ryzen 5 2600 processor has dropped by $10, and both the Crucial BX500 SSD and Seagate Constellation ES HDD have slightly dropped in price, saving us a crisp two dollarinos each.

MID-RANGE

INGREDIENTS

PART			PRICE
Case	Fractal Design Meshify C		$90
PSU	550W Corsair CX550 80+ Bronze	**NEW**	$53
Mobo	Asus ROG Strix B450-F Gaming		$119
CPU	AMD Ryzen 7 2700		$220
Cooler	Cooler Master MasterLiquid Lite 240mm RGB AIO		$70
GPU	MSI GeForce RTX 2060 Ventus 6GB	**NEW**	$350
RAM	16GB (2x 8GB) Ballistix Sport LT @ 3,200MT/s	**NEW**	$84
SSD	250GB Samsung 970 Evo Plus M.2 PCIe SSD		$68
HDD	1TB Seagate Constellation ES 3.5-inch HDD		$36
OS	Windows 10 Home 64-bit OEM		$100

Approximate Price: $1,190

OUR MID-RANGE BUILD is looking mighty fine this month. Before changing a thing, we'd already saved a cool 50 dollars—most of it on the Ryzen 7 2700 and the 250GB 970 Evo SSD, both of which have dropped in price by $20, along with an 11-dollar saving on the Strix B450-F mobo. With that in mind, we exercised a little creative license, and decided to trade out a few pieces. First off, a new Sport LT RAM kit from Ballistix gave us an extra 200MT/s to work with without damaging our budget. Zotac's 6GB RTX 2060 had jumped up by $20, so we swapped it out for MSI's offering to keep our GPU expense at $350. The boost clock on this MSI RTX 2060 is slightly more conservative than the Zotac card, but in terms of value for money, we're still satisfied. Finally, we swapped out the PSU; sticking with Corsair but going from a CX550M to a CX550 to save seven dollars.

TURBO

UPGRADE OF THE MONTH

16GB (2x 8GB) BALLISTIX SPORT LT @ 3,200MT/S

If you're planning—or even just considering—a gaming build right now, Ballistix should be one of your first ports of call when looking at memory, particularly if what you're after is a reasonably priced 1080p or 1440p rig. The Sport LT series is a good example of what it offers; a decent variety of capacities with high-speed options available at sensible prices. The ability to snap up a higher frequency RAM kit for a similar price is something to keep an eye out for if you're repping Team Red; Ryzen CPUs benefit significantly from higher memory speed, meaning that a few hundred extra MHz translate neatly to a few extra percent in processor performance. **$84, http://ballistixgaming.com**

THESE PRICES WENT ALL OVER the place this month. Seriously, go check out the last issue for proof. The 32GB 3,200MT/s Vengeance RGB Pro memory dropped by $45—a surprise, to be sure, but a welcome one—and the Threadripper CPUs have all been trickling down in price bit by bit, with the 2950X down by 10 dollars. Our chosen motherboard jumped up a bit, but we were able to snag a brilliant saving in the form of the 850 GQ from EVGA, a steal at $90 that provides more wattage for a powerful build.

A quick swap from MSI to Zotac saved us $20 on the RTX 2080, and balanced the cosmic scales from our opposite change in the mid-range build. We were compelled to swap back to an AIO cooler after dabbling in air cooling for this build last month. The NZXT Kraken X52 is more expensive than the Be Quiet! Dark Rock Pro it replaced, but handles heat from CPU-heavy processes better. With high-end processors, liquid cooling is often the way to go, and AIO coolers make that process easy.

Storage demanded no changes; last month's upgrade of the month, the 512GB Aorus RGB SSD, remains solid, and Seagate's HDD prices have stayed balanced. NXZT's H700i case rose in price by five dollars, but savvy shoppers will likely be able to find it on sale for cheaper anyway. Overall, we made a clear saving this month: 40 dollars less. A successful result to round out our build blueprints.

For more of our component recommendations, visit www.pcgamer.com/hardware/buying-guides/

INGREDIENTS

PART			PRICE
Case	NZXT H700i		$185
PSU	850W EVGA 850 GQ 80+ Gold	NEW	$90
Mobo	ASRock X399 Phantom Gaming 6		$250
CPU	AMD Threadripper 2950X		$830
Cooler	NZXT Kraken X52 240mm RGB AIO	NEW	$130
GPU	Zotac Gaming GeForce RTX 2080 8GB	NEW	$680
RAM	32GB (2x 16GB) Corsair Vengeance RGB Pro @ 3,000MT/s		$180
SSD	512GB Gigabyte Aorus RGB M.2 NVMe		$120
HDD	2x 2TB Seagate BarraCuda ST2000DM006		$120
OS	Windows 10 Home 64-bit OEM		$100

Approximate Price: $2,685

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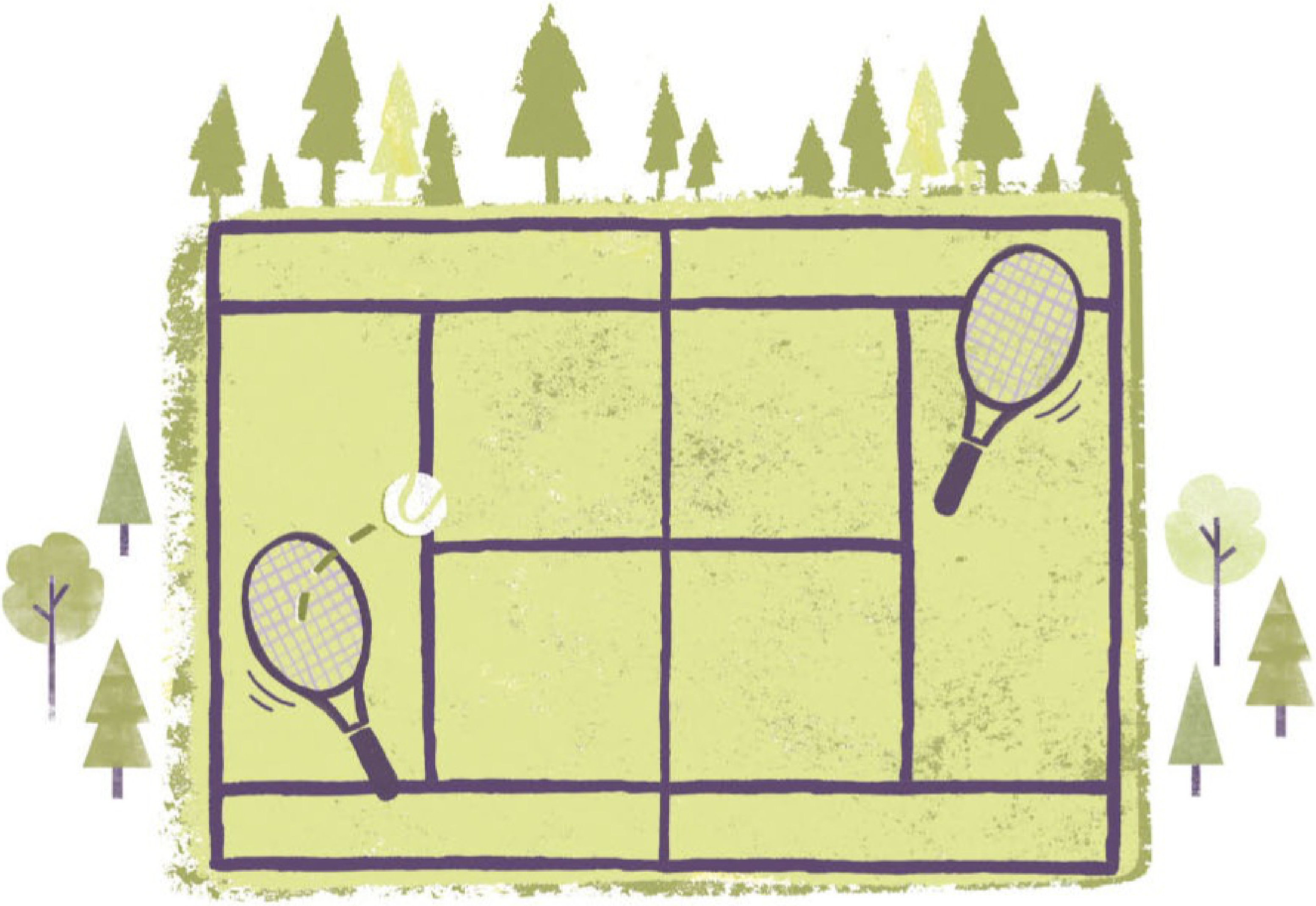

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UNFAO, Global Forest Resources Assessment 2005-2015

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